Journal

WATER POLLUTION CONTROL FEDERATION

Special Features

1960 Literature Review, Part II—Research Committee
Industrial Wastes, Including Radioactivity

Raw Sewage Lagoons—Neel et al.

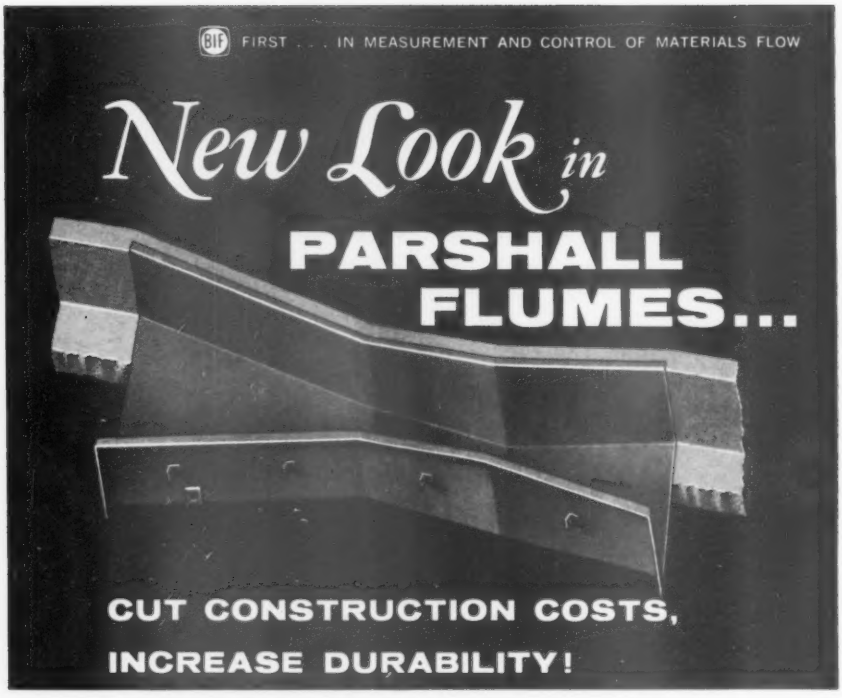
Industry and Pollution—Steffen

Sludge Disposal—Shafer

Public Relations—Sperling

Operator's Manual

JUNE 1961



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Volume 33 **June 1961** **Number 6**

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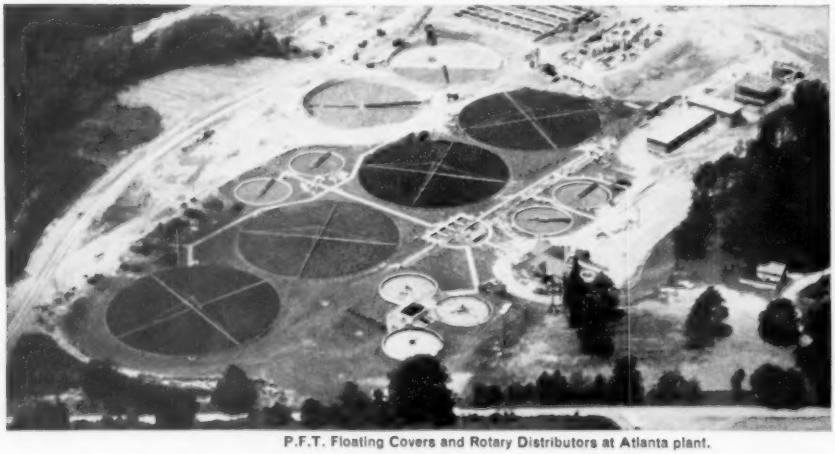

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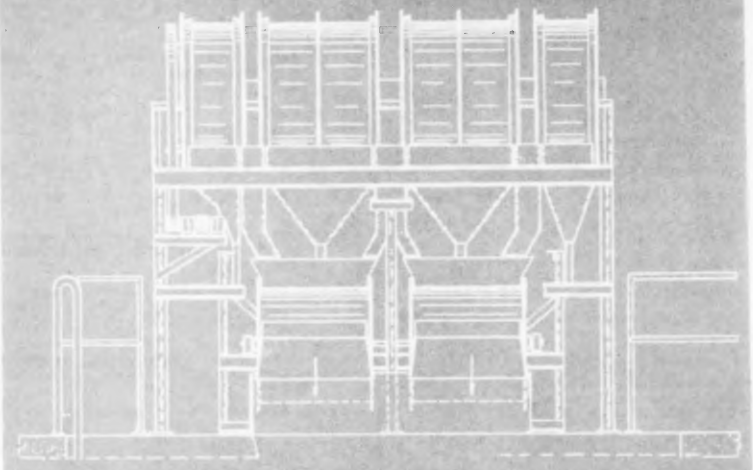

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Ohio	June 14–16	Statler-Hilton Hotel, Cleveland
ISP (England)	June 19–23	Brighton, England
Pennsylvania	Aug. 9–11	Pennsylvania State University, State College
New Zealand	Aug. 28–29	Metro. Drain. Bd. Conf. Rm., Auckland, New Zealand
Kentucky-Tennessee	Sept. 11–13	Brown Hotel, Louisville, Ky.
Germany	Sept. 12–16	Hamburg, Germany
Georgia	Sept. 20–22	Georgia Institute of Technology, Atlanta
South Dakota	Sept. 20–22	Sheraton Hotel, Rapid City
Missouri	Oct. 1–3	Kentwood Arms Hotel, Springfield
North Dakota	Oct. 4–6	Gladstone Hotel, Jamestown
Canada	Oct. 22–25	Hotel Mt. Royal, Montreal, Quebec, Canada
Pacific Northwest	Oct. 25–28	Hotel Winthrop, Tacoma, Wash.
Florida	Oct. 29–Nov. 1	Cherry Plaza Hotel, Orlando
New England	Nov. 1–2	Northampton Hotel, Northampton, Mass.
Nebraska	Nov. 8–9	Hotel Lincoln, Lincoln
South Carolina	Nov. 10	Richland County Health Center, Columbia
North Carolina	Nov. 13–15	George Vanderbilt Hotel, Asheville
Indiana	Nov. 15–16	Hotel Washington, Indianapolis
Oklahoma	Nov. 27–Dec. 1	Oklahoma State University, Stillwater

* See preceding left-hand page for full name.

THIRTY-FOURTH ANNUAL MEETING

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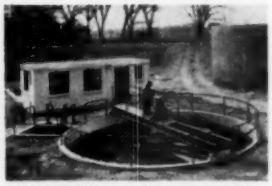

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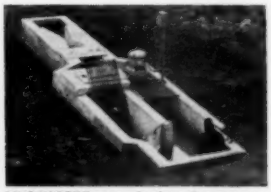

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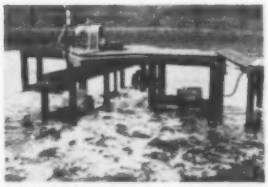

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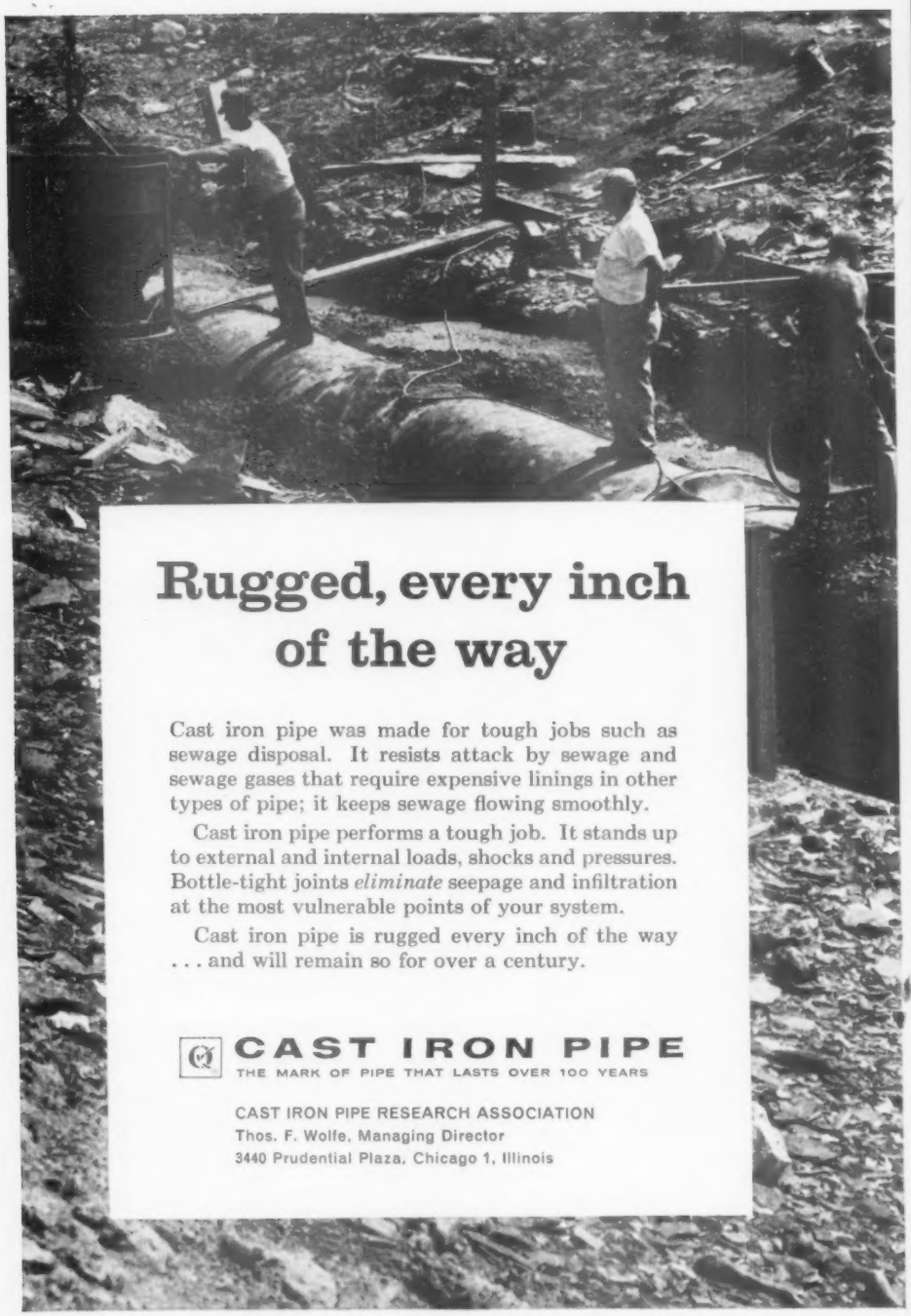

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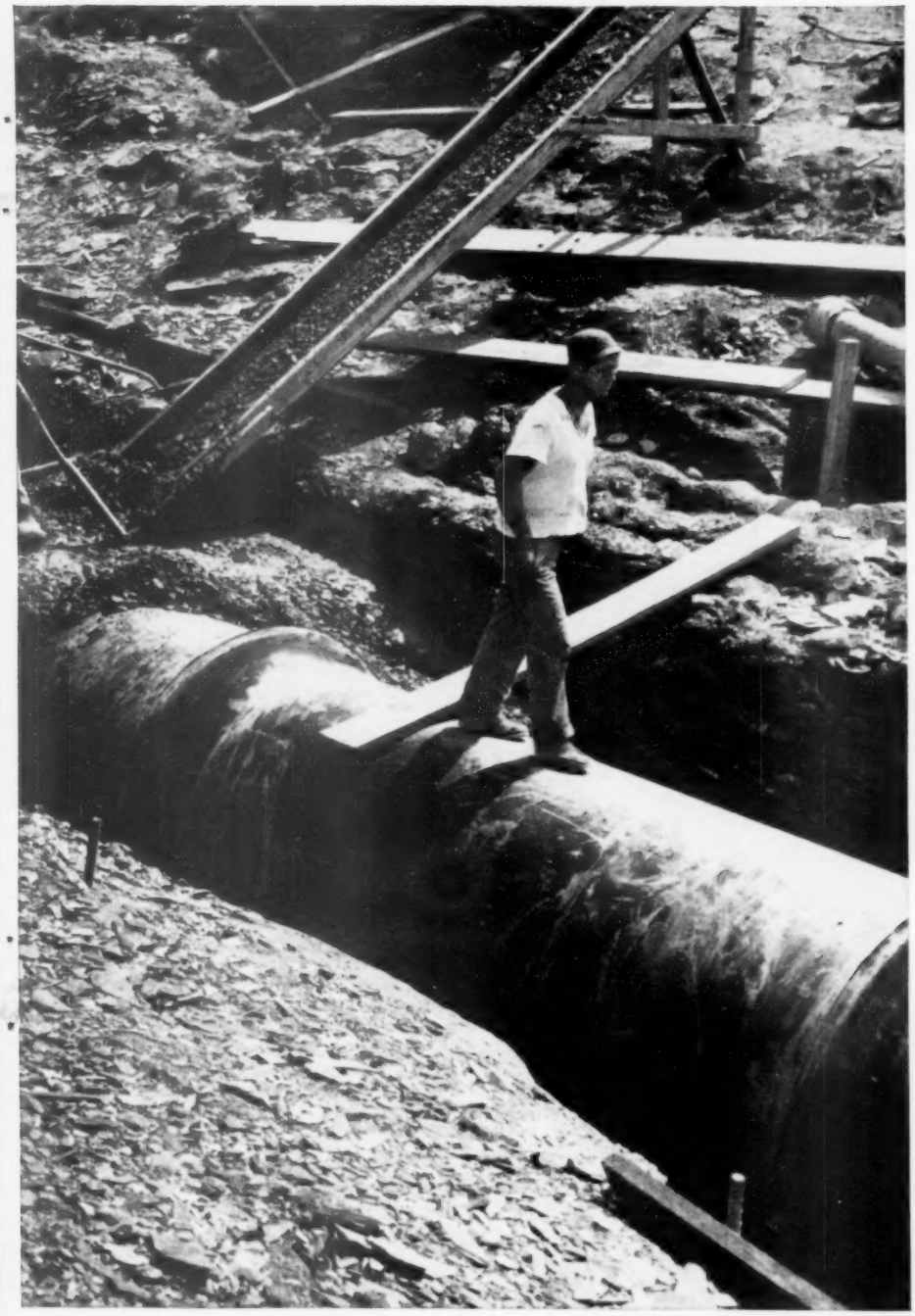

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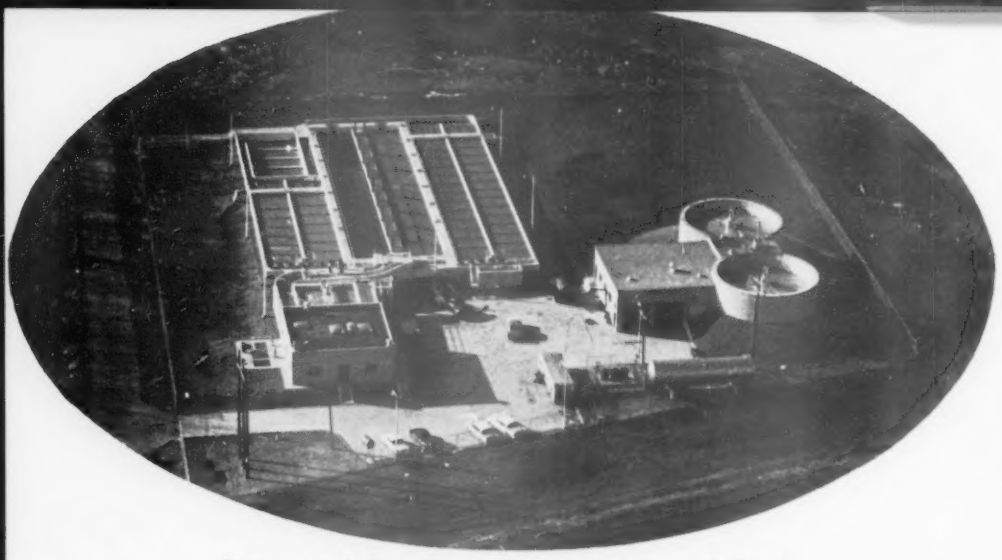
4 After insertion and rotation of retainer ring in bell, the lugs on retainer ring are in back of and in register with internal flange segments in bell. Lead lock is partially inserted into recess between the bell and retainer ring.

5 Lead lock completely inserted in recess is being caulked in place by hammer blows on a wide caulking iron.



Logansport, Indiana, Sewage Treatment plant was designed by Henry B. Steeg and Associates, Indianapolis, Indiana.

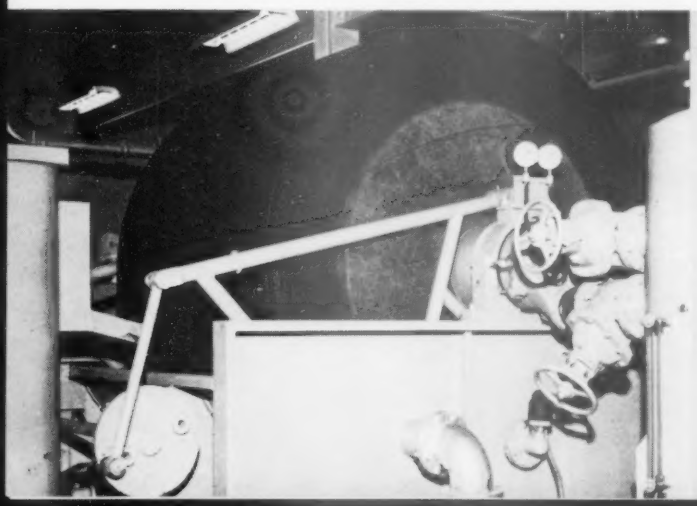
Cake Moistures Average 68.8% with EIMCOBELT® Filter at Logansport, Ind.

Low cake moisture is only one of several ways this EimcoBelt continuous belt filter results in low costs dewatering a primary activated digested sludge at the Logansport, Indiana, Sewage Treatment plant.

Other cost-cutting advantages of the 8-ft. diameter by 6-ft. EimcoBelt filter — complete freedom from filter medium blinding . . . high vacuums . . . low chemical costs . . . ability to discharge thin cakes . . . negligible maintenance. Total sludge dewatering cos at Logansport — $9.80 per ton of dry cake.

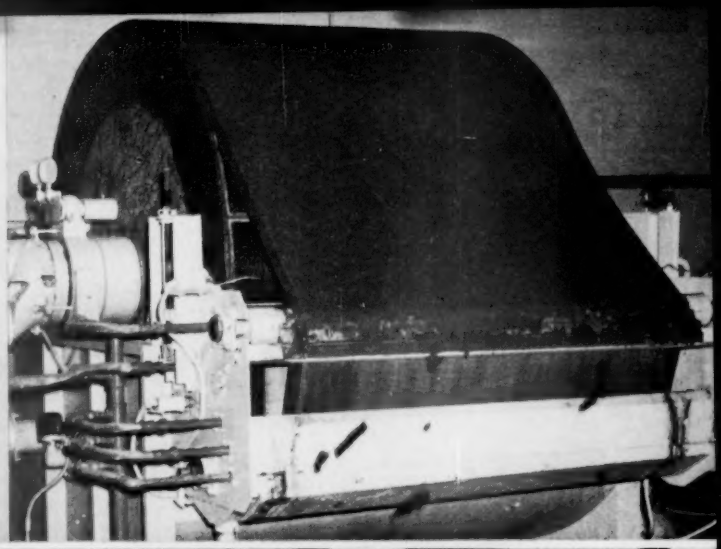
In dozens of other sewage treatment plants, too, EimcoBelt filters are setting new, high operating records, dewatering all types of sewage sludge.

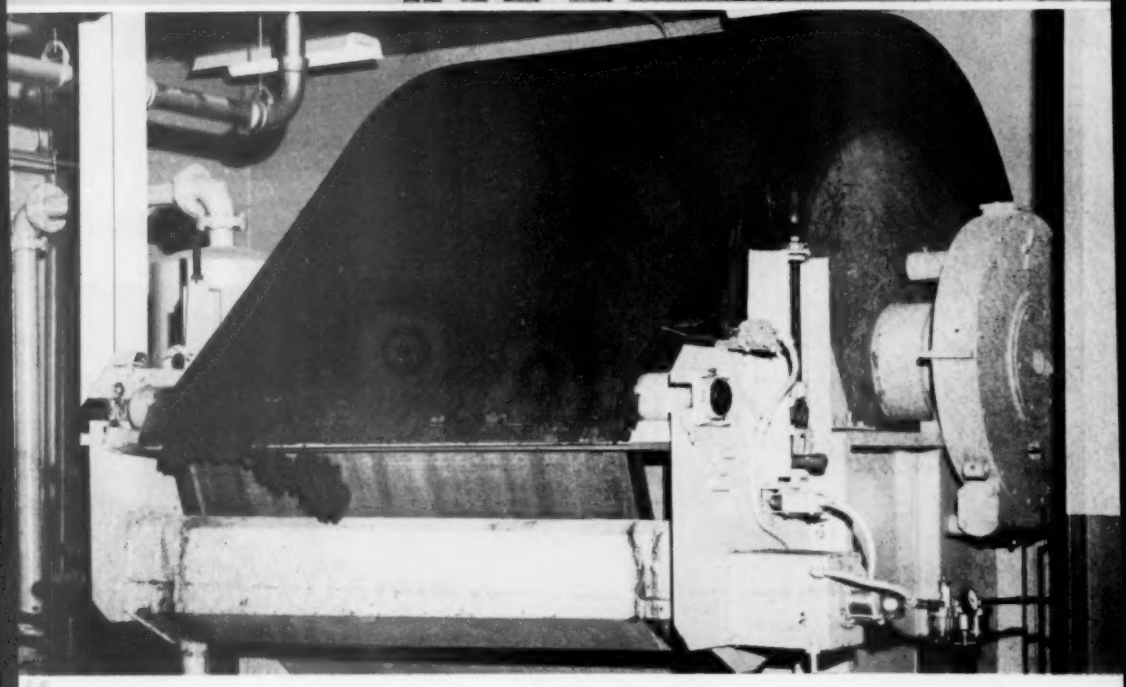
The Eimco representative in your area will be glad to sit down with you and your consultants and provide specific facts on how EimcoBelt filters can reduce costs in your plant. Call him, and write Eimco Filter Division, for Bulletin FJ-2053.



Hy-Flow filter valve, developed by Eimco, eliminates all right angle bends in passages, resulting in the most effective use of vacuum.

High vacuum levels of 20-26-in. Hg. can be maintained across the face of the drum on EimcoBelt filters. Improved seal eliminates end leakage.





EimcoBelt filters remove the belt filter medium from the drum continuously for cake discharge and cleaning. High velocity sprays wash the medium clean, front and back, before it is returned to the drum. No fall-off in filtration rate caused by progressive blinding.

The EIMCO® corporation

Head Office: Salt Lake City 10, Utah, U.S.A.
Export Office: 52 South St., N.Y.

"Advanced Engineering and Quality Craftsmanship Since 1884"

B-738

AMERICAN

First and last it pays to make concrete plans for your community with the best possible medium for water transmission—CONCRETE PRESSURE PIPE.

Your community's future demands concrete planning

Why are so many communities turning to concrete pressure pipe for their main water lifeline of the future? Farsighted waterworks authorities recognize that the present critical demands, brought about by our recent population and industrial explosion, may easily be doubled within the next 25 years.

They also recognize that, with concrete pressure pipe, plans for the future are laid on a solid foundation of an exceptional life span, minimum maintenance requirements and virtually no replacement costs. But most of all, their planning can be accurate, because concrete pressure pipe's initial high carrying capacity will remain unimpaired in years to come when demands on the line will be highest.

WATER FOR GENERATIONS TO COME

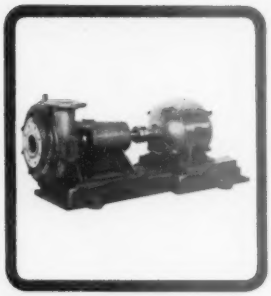
Concrete PRESSURE Pipe

CONCRETE PRESSURE PIPE ASSOCIATION

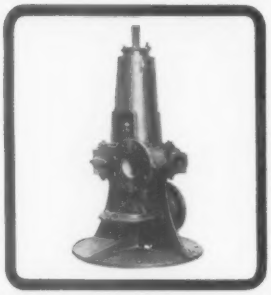
228 North LaSalle Street • Chicago 1, Illinois

PERFORMANCE-PROVED

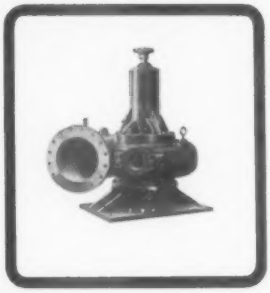
Trouble-free years of operation without replacement of major parts, with only routine maintenance, isn't just a claim—C. H. Wheeler pumps are 40 years' performance-proved on the job. (Pumps having higher capacities than those illustrated are available.)



HORIZONTAL NON-CLOG PUMPS. Sewage disposal plants prefer these units for unscreened liquids, sewage. Non-clog impeller, ball bearings, renewable shock absorber. Sizes: 3″—24″. Capacities: 40-5000 gpm. Heads to 160 ft.

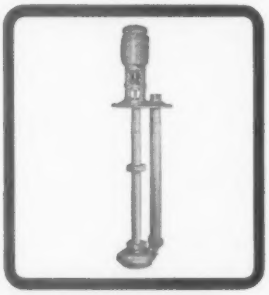


VERTICAL NON-CLOG PUMPS in Open-Shaft and Sentry types for dry pit installations. Many engineering advancements bring higher pump efficiency, lower maintenance costs. Service, performance data and sizes same as Horizontal Non-Clog Pumps.



VOLUTE PUMPS OF MIXED FLOW OR NON-CLOG DESIGN are ideal for many pumping applications including: screened sewage, for drainage, irrigation, flood control and industrial water supply. Horizontal and vertical designs available. Sizes: 12″—48″. Capacities: 3000-100,000 gpm.

AXIAL AND MIXED FLOW PUMPS, in horizontal and vertical designs, for flood control, primary water supply, industrial process work, drainage, etc. High-capacity, low-to-medium heads. Standard or pull-out construction. Sizes: 8″—72″. Capacities: 5000-220,000 gpm and over.



NON-CLOG SUMP PUMPS for heavy-duty drainage, underpass service and sewage disposal. Ideal for industrial and municipal lift stations. These pumps have enclosed, non-clog impellers with wide waterways. Sizes: 3″—14″. Capacities: 20-4000 gpm at heads to 160 ft.

C. H. WHEELER MFG. CO.

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Affiliates:

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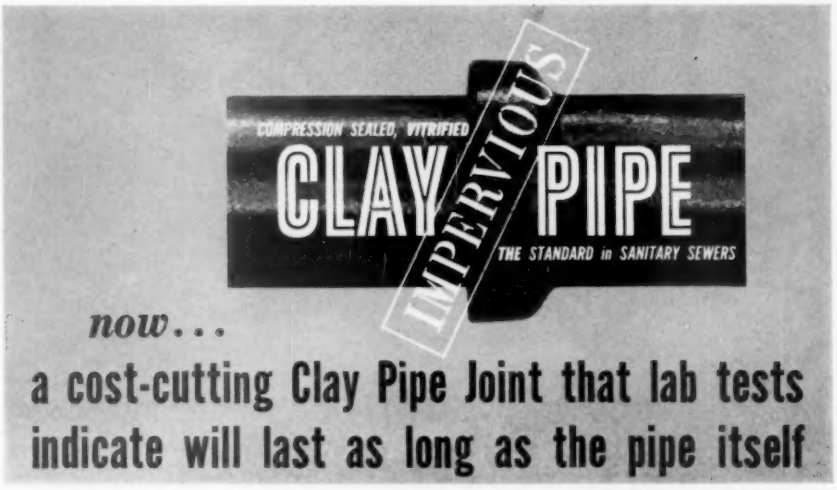
KLIPFEL VALVES, INC.

Centrifugal, Axial and Mixed Flow Pumps • Ejectors • Steam Condensers • Marine Auxiliary Machinery • Nuclear Components

THE C. H. WHEELER PUMP TESTING LABORATORY can test pump capacities of up to 150,000 gpm. Accurate scale models of water intake tunnel structures are built and tested in this laboratory. *See your C. H. Wheeler representative or write direct to C. H. Wheeler for help with your problems.*



now . . .

a cost-cutting Clay Pipe Joint that lab tests indicate will last as long as the pipe itself

The secret's in the joint—developed after years of research by the Clay Pipe Industry's modern laboratory at Crystal Lake, Illinois.

The joints are self-sealing, offering dramatic savings in installation time and trouble. Made of resilient materials, they are designed to resist corrosion from acids and gases, infiltration and exfiltration.

Accelerated lab and field tests indicate these new joints will last as long as the pipe itself—giving engineers and contractors the new standard in high performance and trouble-free sanitary sewer lines.

These revolutionary joints are now available on lifetime Vitrified Clay Pipe all over the country on sizes from 4 inches to 36 inches, in some areas, up to 42 inches. They are built to exceed rigid ASTM and other applicable standards.

Send for full details on this installation cost-cutting research breakthrough. Find out how

Research combines clay's long life with fastest jointing ever.

COMPRESSION SEALED, VITRIFIED
CLAY PIPE
IMPERVIOUS
THE STANDARD in SANITARY SEWERS

NATIONAL CLAY PIPE MANUFACTURERS, INC.
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Please send me full details on the new factory-made compression joints on Clay Pipe.

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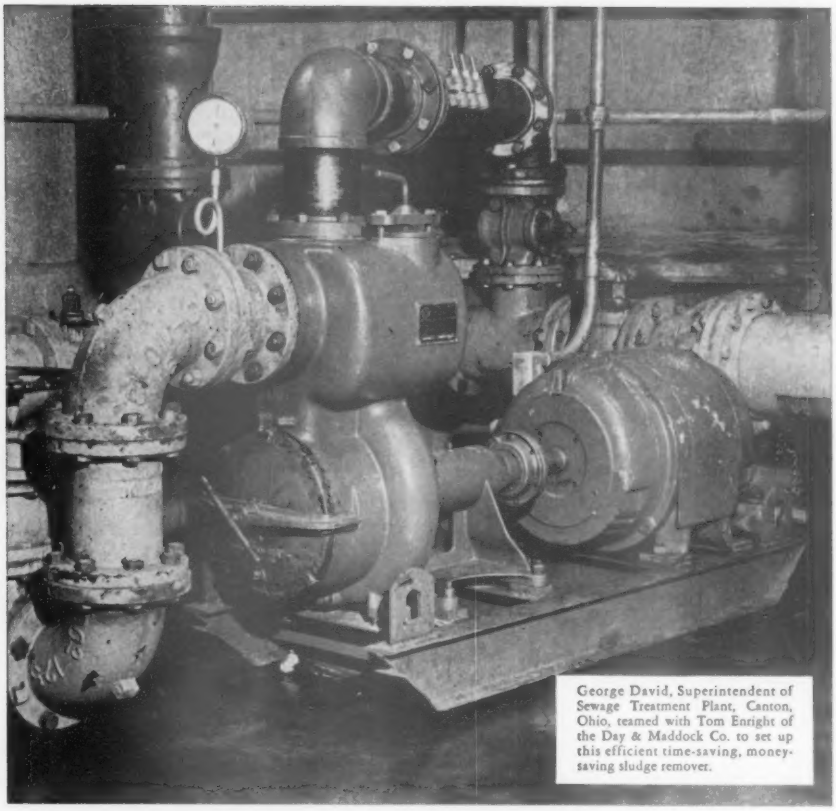
B-51 WP



George David, Superintendent of Sewage Treatment Plant, Canton, Ohio, teamed with Tom Enright of the Day & Maddock Co. to set up this efficient time-saving, money-saving sludge remover.

Recirculation and Cleaning Pump solves Canton Digester Problem

Gorman-Rupp Sewage Pump cleans with no downtime and major savings

Problem—To remove 7-years' accumulation of sludge from 10 huge digesters. With mechanical shoveling devices, it cost $5000 to clean only one digester. And during cleaning, digester was totally inoperative for 6 weeks.

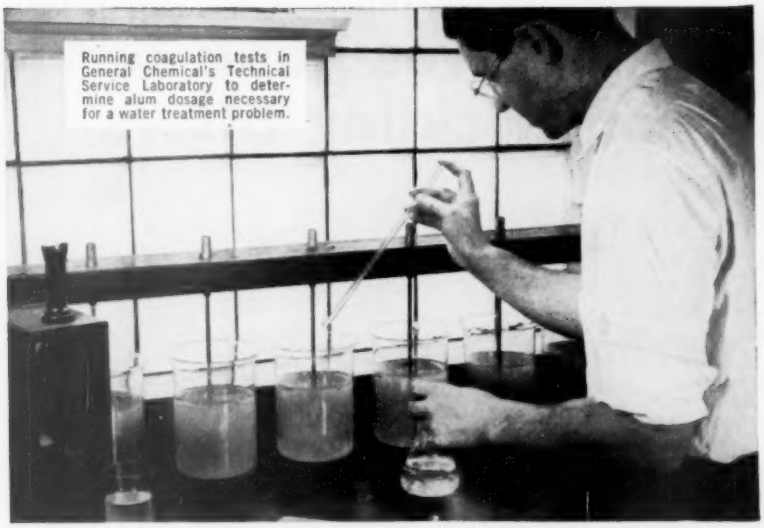
Answer—A Gorman-Rupp Model 16A2-B Pump. Its unique action first agitates sludge into a common mixture by circulating digester liquid under pressure. Then, with valves reversed, pump draws off liquid and suspended solids for disposal.

Result—Each digester could be cleaned in only 21 days. Only outlay is cost of 6″ pump, electric motor, and labor of opening and closing 2 valves twice a day.

4″ and 6″ pumps can be connected to your power or ordered complete with power units. Write for complete specifications.

Fast Action End Plate. Releases for access to impeller and renewable wear plate. Impeller is 2-vane trash type that handles spherical solids up to 2½″ in diameter.

THE GORMAN-RUPP COMPANY
305 Bowman Street • Mansfield, Ohio
Gorman-Rupp of Canada, Ltd.,
St. Thomas, Ontario



Running coagulation tests in General Chemical's Technical Service Laboratory to determine alum dosage necessary for a water treatment problem.

in GENERAL CHEMICAL ALUM

Another difference is TECHNICAL SERVICE

As the country's primary producer of aluminum sulfate, General Chemical constantly helps customers solve technical problems involving the use of alum. Results? Improved efficiency and reduced operating costs for them. Here are some of the services our Technical Service Department offers:

- Supplying basic information helpful in planning design and installation of storing, pumping, metering and feeding facilities.
- Suggesting improvements to eliminate existing storing and handling problems.
- Providing chemists and operators with physical and chemical data necessary for the most effective use of alum.
- Assisting in laboratory tests and plant trials.
- Running check analyses in our own laboratories.

In water and sewage plants, our specialists provide valuable help and guidance on storage, handling and feeding problems, as well as the important conversion from dry to liquid alum. They can help plant operators establish the best alum dosage. They recommend coagulation aids to improve flocculation in difficult water or waste treatment conditions.

This kind of Technical Service is one of the reasons why General Chemical is a good company to do business with for *your* plant's aluminum sulfate requirements. We will welcome the opportunity to serve you.

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Allied Chemical

GENERAL CHEMICAL DIVISION
40 Rector Street, New York 6, N. Y.

CITY OF SALISBURY, MARYLAND, POLLUTION CONTROL PLANT

Poxitar® gives good service on trickling filters

Mr. Carey White, Assistant Superintendent, checks one of his trickling filters (112-foot-diameter). Filters are painted with tough-service Poxitar. Reports Mr. George K. Miles, design engineer: "We sandblasted to bare metal to remove the earlier paint system completely. Then we put on two coats of Inertol Poxitar. Regular inspection shows that despite the difficult service involved, it is performing satisfactorily. After approximately one year's service we are pleased with the protection Poxitar offers."

Poxitar, coal-tar epoxy, protects against constant submersion, chemicals, fumes and acids. It bonds exceptionally well. Poxitar contains an ample — not simply adequate — amount of epoxy resin. And only enough coal-tar pitch is added to balance the formulation. Poxitar is applied cold (do not heat). It gives fast, high-build protection; cures uniformly throughout the heavy film by polymerization.

Poxitar is only one of the more than 100 different coatings made by Inertol Company. At Salisbury alone, Inertol No. 49 Thick, Inertol No. 49, Inertol Standard Thick, Glamortex®, Rustarmor®, Ponkote®, Ramuc® Utility Enamel and their matched primers were used.

There's an informative bulletin on Poxitar —Bulletin S-600, giving specifications and other data. Write for it today. As always, our Technical Service Department will gladly cooperate in solving your painting problems, without cost or obligation.

Inertol makes a complete line of quality coatings for pollution control, water and industrial wastes plants and swimming pools.

CONSERVE WATER

Inertol®

INERTOL CO., INC.

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Steel

Strong,
Durable,
Economical

Armco
SMOOTH-FLO
Provides
Top Flow
Capacity,
Long
Service Life

New steels are born at Armco

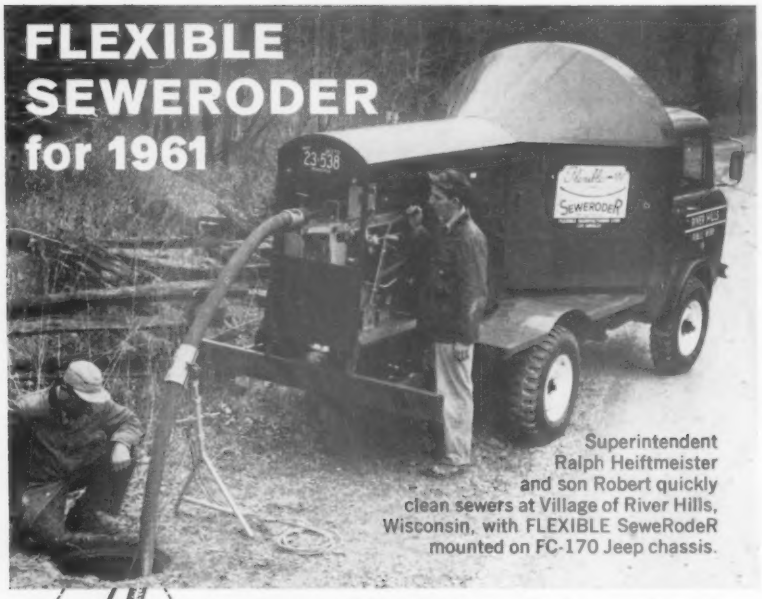
Armco SMOOTH-FLO® Sewer Pipe – corrugated galvanized steel with a smooth, centrifugally-applied bituminous lining that completely fills the inside corrugations – combines top flow characteristics with strength *and* abrasion resistance. For severe corrosive or flow conditions, lining and coating are bonded to the base metal by asbestos fibers.

SMOOTH-FLO Structures, available in a wide range of lengths, gages and diameters, are flexible. They withstand heavy loads and shock without cracking, breaking or disjointing. Joints are watertight and defy separation by roots and frost action.

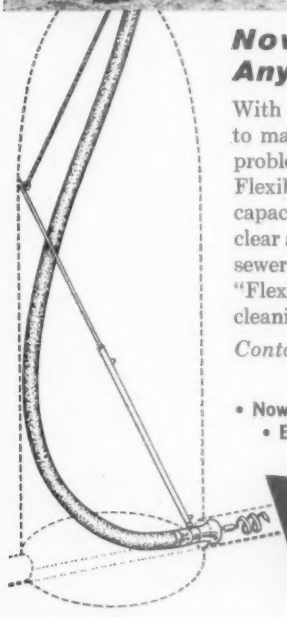
See how Armco SMOOTH-FLO can meet your design requirements. Write **Armco Drainage & Metal Products, Inc., subsidiary of Armco Steel Corporation, 6651 Curtis Street, Middletown, Ohio.**

ARMCO Drainage & Metal Products

FLEXIBLE SEWERODER for 1961



Superintendent Ralph Heiftmeister and son Robert quickly clean sewers at Village of River Hills, Wisconsin, with FLEXIBLE SeweRodeR mounted on FC-170 Jeep chassis.



Now This Village Can Whip Any Sewer Emergency – FAST!

With a population of 1257 and 20 miles of sewer to maintain, the Village of River Hills solved its problems with existing manpower. They chose the Flexible '61 SeweRodeR and have tripled cleaning capacity for preventive maintenance: the crew can clear a stoppage anywhere along the entire 20-mile sewer system in 30 minutes. Village, town or city – "Flexible" has the equipment to solve any sewer cleaning problem FAST and economically.

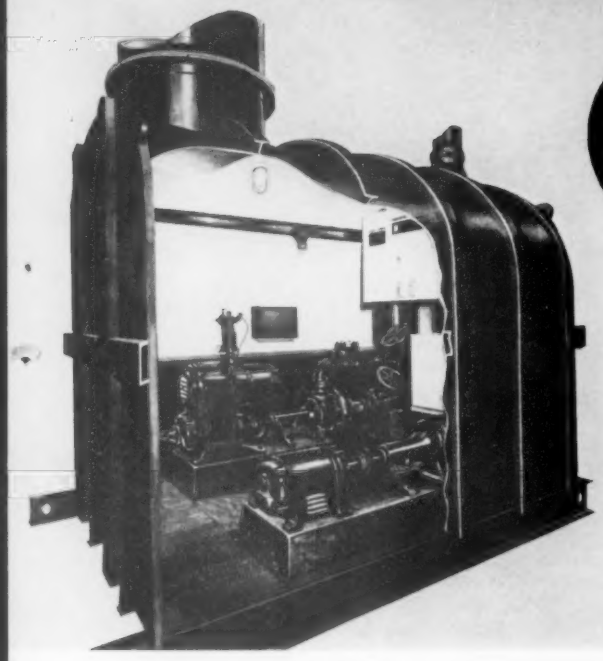
Contact your Flexible Sales Engineer today.

1961 FEATURES:

- **Now more positive rod drive for smoother operation**
- **Economical 48" rods • 900 ft. reel capacity**
- **4 to 4,000 lbs. controllable push-pull power**
- **Instantly reversible.**

FLEXIBLE, Inc.

415 SOUTH ZANGS BLVD., DALLAS, TEXAS
3786 DURANGO AVE., LOS ANGELES 34, CALIF. • 1005 SPENCERVILLE ROAD, LIMA, OHIO

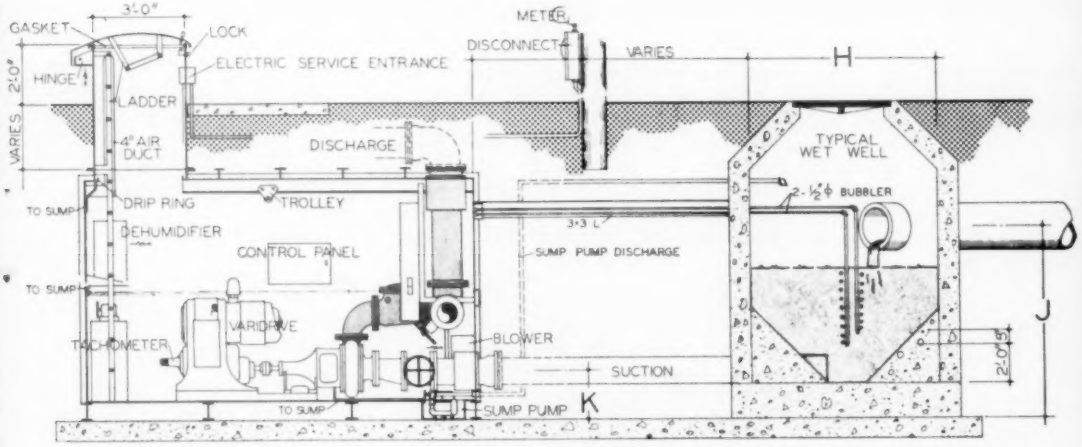


TEX PACKAGED **QUAD** PUMP STATION

the 1st
PACKAGED PUMP STATION DESIGNED TO FIT THE EQUIPMENT

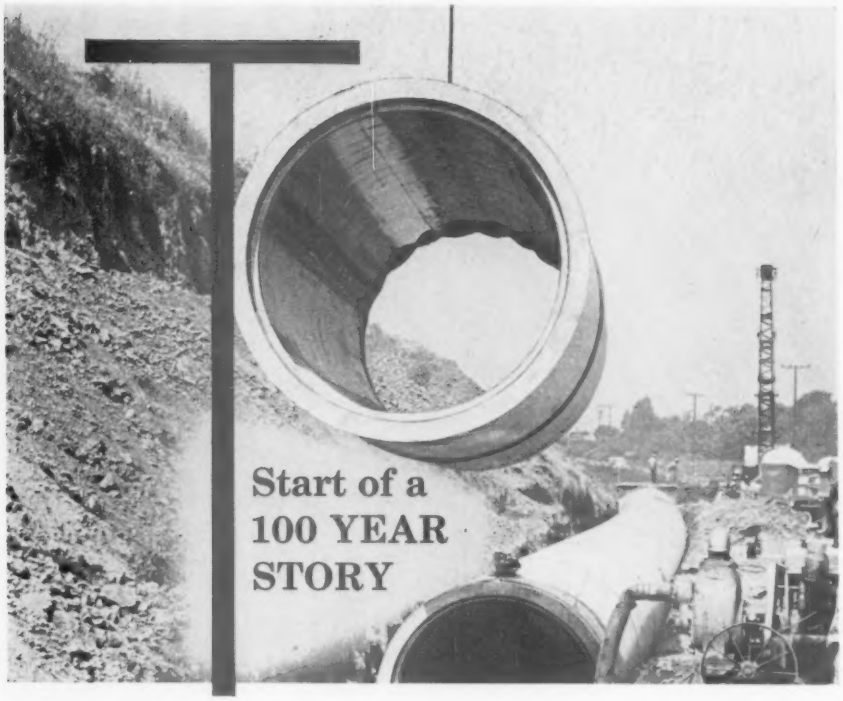
MORE USEABLE FLOOR SPACE

- More Room For Future Expansion of Pumping Units
- More Room For Servicing of Equipment
- More Room To Use Variable Speed Pumps To Match The Pump Capacity To The Rate of Sewage Inflow



Write Today for the New TEX-QUAD CATALOG No. TQ-61. It Gives Complete Information On This New, Rectangular Packaged Pump Station.

TEX-VIT
MANUFACTURING COMPANY
Formerly TEX-VIT Supply Company
P. O. BOX 117-J MINERAL WELLS, TEXAS



This reinforced concrete sewer will be in service generations from now, because concrete surpasses all other materials. Most concrete sewers do not require protection, but when strong chemical effluents or oxidized H_2S are a problem, only T-LOCK AMER-PLATE provides positive protection. T-LOCK AMER-PLATE is a high molecular weight polyvinyl chloride sheet which is cast into the concrete during manufacture.

T-Lock Amer-Plate meets all the requirements of the ideal sewer lining:

- T-Lock is extremely dense and impervious. Permanently protects concrete from chemical effluents and H_2S corrosion.
- T-Lock is permanently flexible. Tensile strength minimum is 200 psi; elongation at break is a minimum 200%.
- It is mechanically bonded to the pipe. Pull tests result in the breakage of concrete before T-Lock fails.
- T-Lock withstands 40 psi back pressure, equal to a ground water head of 85 feet.
- T-Lock has a smooth, highly abrasion resistant surface . . . maintains its N factor of .010 indefinitely.

There are no other materials – paints or troweled-on mastics, mortars, sacrificial aggregates or admixes – which meet these vital requirements.

Where protection is required, only T-LOCK will do the job. Compromise methods are a gamble which experienced sewer designers will not take; they know it is money wasted to specify linings which will fail within a few years.

Because T-LOCK AMER-PLATE is the only completely satisfactory material on the market today, millions of square feet are now in use in cities throughout the nation.

Amercoat® CORPORATION

For a complete list of users and specifiers, plus technical data, write:

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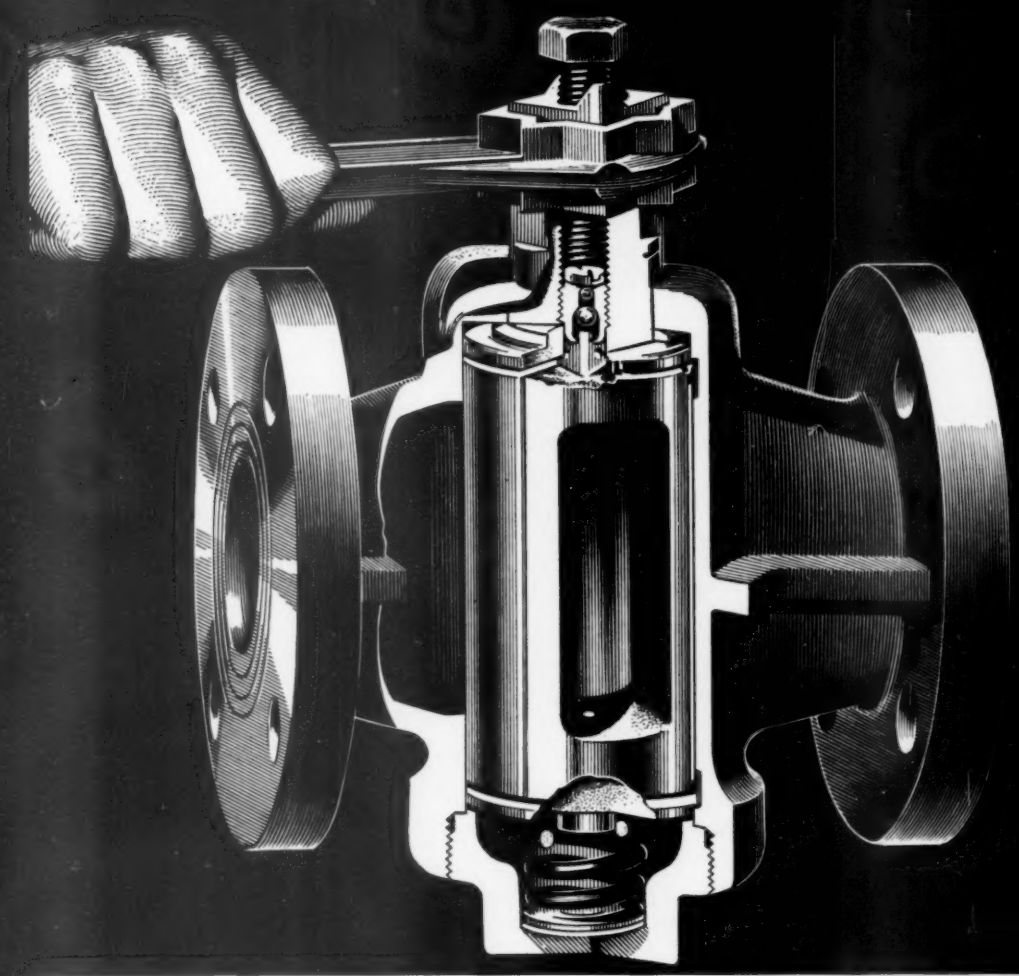
360 Carnegie Ave. Kenilworth, N.J.
111 Colgate Ave. Buffalo, N.Y.
2404 Dennis St. Jacksonville, Fla.
6530 Supply Row Houston, Tex.



HOMESTEAD® LUBRICATED PLUG VALVES

performance you can put your hand on

When you take the handle of a Homestead Lubricated Plug Valve, you know that positive low-cost fluid control is at your fingertips. This Homestead Valve is built to very close tolerance, vital to long, effective operation—two thousandths of an inch maximum tolerance on sizes up to 2″ and three to five thousandths on larger sizes. Its *controlled* high pressure lubricant system guarantees complete coverage of sealing surfaces; protection against corrosion; no contamination of line fluids; and no-stick opening or closing thanks to the downward movement of plug during each lubrication. In short, you get performance you can count on with Homestead Lubricated Plug Valves. Get the full story in Reference Book 39-1. Send for your free copy today.

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HOMESTEAD VALVE MANUFACTURING COMPANY
"Serving since 1892"
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Makers of: Homestead Ball Valves, Cam-Seald, Lever-Seald and Lubricated Plug Valves

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Both indexes contain separate listings by author, subject, and geographical categories, along with full cross-referencing. These features make them complete and easily used references.

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WATER POLLUTION CONTROL FEDERATION

4435 Wisconsin Avenue **Washington 16, D.C.**

Needham, Mass., Installs FIRST Plastic Sewer Main in U.S.A.

"Evanite stops INFILTRATION and EXFILTRATION, has a root-proof joint," says Sewer Superintendent

E. A. Symonds, Needham Superintendent of Sewers, selected Evanite Plastic Sewer Main in 8-inch diameters, plus plastic fittings and 4-inch plastic house connections, after extensive tests established Evanite as impervious to attack by chemicals found in sewage and industrial wastes. It was also determined that Evanite's non-absorptive quality, as compared with existing sewer pipe materials, eliminates percolation through the walls, and has adequate crushing strength for sewer main service under city streets.

Ease of installation also was a factor . . . Evanite can be cut with a saw and rejoined without further machining or working.

Evanite Plastic Pipe is guaranteed for 50 years

Evanite PLASTIC COMPANY

Evanite is the only producer of large diameter plastic sewer mains.

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One of the nation's largest producers of face brick, clay pipe, clay flue lining, wall coping, and related construction materials . . . with over 50 years of faster, friendlier service.

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- **TREATMENT PLANT DESIGN**
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(Produced Jointly with ASCE)

"Sewage Treatment Plant Design," 374 pages of the latest information for those interested in plant design. (WPCF MOP 8).

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Each manual is offered to members at $3.50, and to others at $7.00.

Bring your reference library up to date with the addition of these authoritative volumes.

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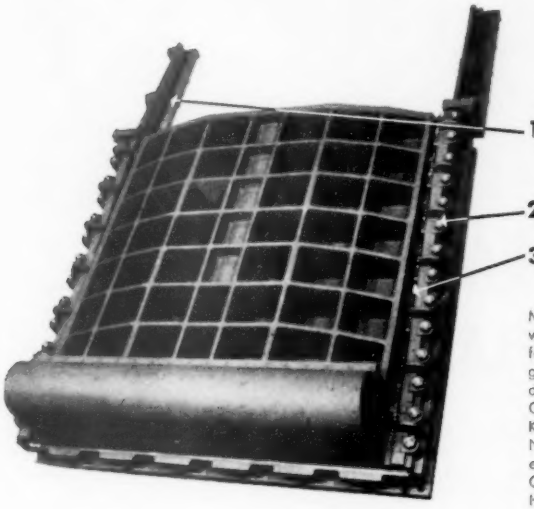
WATER POLLUTION CONTROL FEDERATION

4435 Wisconsin Avenue **Washington 16, D. C.**

2,300 pounds of Everdur used in new 8-ton cast-iron sluice gate



1 ¾" x 3" Everdur facing strips for gate leaf and frame.

2 1½" Everdur bolts and nuts.

3 Everdur adjusting bolts for cast-bronze wedges.

More than a ton of Everdur was used for facing strips and fastenings in this 8' x 8' sluice gate leaf and frame assembly designed and furnished by the Coldwell-Wilcox Division of Krajewski-Pesant Mfg. Corp., New York City. Consulting engineers, Gannett Fleming Corddry & Carpenter, Inc., Harrisburg, Pa.

This direct-pressure type sluice gate is one of two recently installed by Empresa de Energia Electrica at the Quebradona Dam in Columbia, South America, to regulate the flow of potable water to the city of Medellin.

The 100-foot head of water behind the dam exerts 450,000 pounds pressure on each 8 x 8-foot gate. Everdur* (copper-silicon alloy) was selected to seal against this load because of its high strength and corrosion resistance—plus ready workability and weldability. Sewage treatment and waterworks equipment of Everdur has been in service without replacement for a quarter century and longer.

Write for Publication E-11, "Everdur Copper-Silicon Alloys for Sewage Treatment and Waterworks Equipment"—or for technical help in selecting the correct material. Address: Anaconda American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Limited, New Toronto, Ont. 57133L

*Reg. U.S. Pat. Off. 57133

EVERDUR Anaconda's Family of Copper-Silicon Alloys

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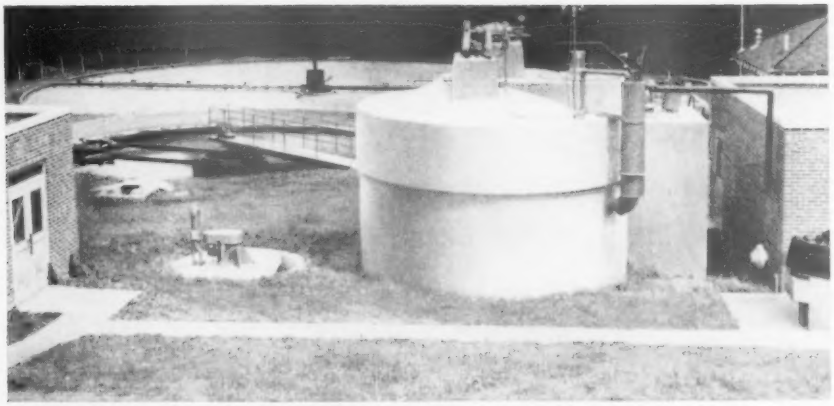

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A REVIEW OF THE LITERATURE OF 1960 ON WASTEWATER AND WATER POLLUTION CONTROL

H. Heukelekian, Chairman, R. M. Manganelli, Vice-Chairman, T. A. Alspaugh, E. J. Berg, H. F. Clark, C. H. Connell, W. E. Dobbins, G. P. Edwards, M. B. Ettinger, D. G. Foulke, T. deS. Furman, P. E. Gaffney, I. Gellman, H. G. Harding, J. D. Helwig, R. D. Hoak, R. S. Ingols, W. M. Ingram, P. W. Kabler, M. Katz, F. W. Kittrell, N. J. Lardieri, H. G. Luley, P. H. McGauhey, R. Porges, A. J. Steffen, C. Straub, C. M. Tarzwell, G. H. Teletzke, W. W. Towne, H. A. Trebler, E. C. Tsivoglou, E. Weisberg, and R. L. Woodward

INDUSTRIAL WASTES

Food Processing Wastes

Canning

A paper by Norgaard *et al.* (125) describes the use of both laboratory and small-scale pilot-plant treatment combinations to study applicable processes to handle wastes resulting from concentration of the fruit canning industry at San Jose, California. Disposal to tidewaters of southeast San Francisco Bay has been a problem for the past 30 yr. The basic processes investigated are: (*a*) anaerobic primary followed by activated sludge or high-rate filter secondary, (*b*) primary sedimentation plus high-rate filter secondary, and (*c*) activated sludge with and without primary sedimentation.

Dietz and Frodey (50) describe the experiences of waste disposal by a Michigan canner using spray irrigation. The paper aptly covers the important aspect of this method of waste disposal, including the ground cover of grasses and trees. Also discussed is successful spraying during winter months.

Another discussion of waste disposal by spray irrigation is presented by Monson (113). He states that the use of this method of waste disposal has increased from a few canners in 1948 to an estimated 250 in 1957.

Davis (46) tells of the use of oxidation ponds to solve the problem of treating wastes from the canning of citrus fruit in Texas.

A paper by Skrinde and Dunstan (150) advises that the activated sludge process, when loaded properly, provides the most efficient treatment of pea processing wastes. They also state that for satisfactory biological treat-

The authors comprise the Research Committee of the Water Pollution Control Federation.

This second of three sections of the Literature Review covers industrial wastes, including radioactive wastes. Because of the extensive coverage, the industrial wastes section on radioactivity is referenced separately from the discussion of other industrial wastes.

The first section, dealing with analytical methods and sewage, was published in the May 1961 issue of THIS JOURNAL. *The third section, on water pollution, will be published in the July 1961 issue of* THIS JOURNAL.

ment the addition of supplementary nitrogen and phosphorus is necessary.

An article (3) tells of an Ohio city that outgrew the capacity of its sewage treatment plant which treated domestic sewage with the wastes of a pickle packing plant. The pickle company then installed a small aerobic digestion plant to treat only their industrial wastes. Most of the sludge resulting from this treatment floats, and is removed by skimming.

Porges (138) presents information on processes and wastes of manufacturing corn chips. The paper does not discuss waste treatment methods.

In an effort to provide a standardized procedure so that the operation of various pilot plants by various investigators can be more uniform, Symons *et al.* (156) outline a procedure for the pilot plant determination of aerobic biological treatability of industrial wastes. The authors compare their proposal to "Standard Methods" with the purpose that various data can then be compared.

A paper by Ziemba (176) describes a company campaign to make employees waste-control conscious. The program was formulated for use at a brewery, but methods described are applicable to all industry.

An article (10) generally covers methods of waste disposal in the food processing industry in England. Also covered are methods of treating reclaimed water for reuse with descriptions of the new cooling and treating plant for can cooling water.

Ammerman and DesRosier (1) discuss aerobic decomposition of wastewater from tomato processing by aeration, by the addition of nitrates, or by spray irrigation without producing odors.

Pahren and Saenz (133) outline information collected in Costa Rica on the feasibility of treating wastewater from processing coffee cherries in stabilization ponds.

Data are presented by Cyr (45) for amounts, properties, and pollution loads of wastewater resulting from the preservation of vegetables and fruits in Canada. Treatment processes are described and conditions of their use are discussed.

A paper by Pailthorp (134) covers pilot plant work and evaluates color removal from beet waste using high-rate trickling filters when the waste is treated in conjunction with domestic sewage.

Sugar

Keller and Huckabay (88) discuss the background, method of approach, and success that has been achieved in abating pollution in the Louisiana cane sugar industry.

The polluting effects of sugar beet factory waste, methods of waste treatment and legislation concerning discharge of these wastes to surface waters in France and Italy are discussed by Maldura and Vivier (102).

A paper by Bruckner (35) tells of the reuse of water and the sedimentation of fluming and washing waters with special reference to sand removal.

Zagrodski and Walerianczyc (175) report on the reuse of diffusion and press waters after fine screening in beet sugar factories.

The reuse of wastewater treated by the Landsberg system of circulation is recommended by Bulicek (37).

Votava (166) discusses the problems of water economy in sugar beet factories.

Dairy Wastes

Graaf and Baltjes (68) describe waste saving and measurement efforts in Holland and show important reductions in waste below what was previously considered standard losses (Wagner system). Magnusson (99) also reports on the good waste-saving efforts in that country. Specifically he mentions the possible saving of solids by sedimentation or centrifugation of but-

ter wash water. The solids are used for animal feed.

The Dairy Institute in Kiel (169) has made another careful waste survey in a German dairy for one full week by installing water meters in all cooling water lines and by taking samples continuously in proportion to the flow in various waste lines. The immediate results of the survey were improved waste saving and better seasonal distribution of certain activities, such as steaming of potatoes for cattle feed. The dairy discharges its waste to a stream (1.8 cfs or 800 gpm in July) that flows 3,000 ft into a pond (5 acres) which is used for fishing. The daily load put on the stream by the dairy was equivalent to 2,000 population. The stream already had 20 mg/l BOD at the point where the plant waste was discharged. The stream and the pond did a good purification job as the BOD at the outlet averaged about 10 mg/l. Still the installation of a 20,000-gal capacity flow equalizing tank at the dairy is recommended in order to even out the load.

The University of Wisconsin group (93) has issued a revised report on spray irrigation. It is a valuable manual for installation and operation of this type of treatment which is very popular where conditions are suitable. Flynn (60) reports from Australia on treating daily up to 20,000 gal (Imperial) of combination casein and cheese whey plus 44,000 gal of washings which are pumped to a 165,000-gal reservoir. Sufficient river water is added so that the whey is diluted 1 : 5. The spray irrigated area is 34 acres of pasture with 3 hydrants. Two 5-in. portable aluminum lines are moved whenever the field appears saturated. This keeps one man occupied almost full time in the flush season. The irrigation pump is 4-in., 50 hp. The main header (6-in.) is fibrolite pipe. Cattle raising is expected to pay for the installation and operation costs. Yerex (174) describes a spray irrigation installation in New Zealand in connection with a 600 ton/yr casein factory. In the flush there are 16,000 gpd (Imperial) of whey of which 6,000 gal are returned to the farmers. The rest, together with wash waters, or a total of 27,000 gal are sprayed on pasture land. The total irrigated area is 70 acres with 15 hydrants. Fifteen sprays (45-ft radius) are moved daily. About 2.2 acres are sprayed each day, so it takes a month to make the circuit. Fresh water follows the whey mixture so that everything is well rinsed at the end of the run.

Graaf (67) describes several spray irrigation tests in Holland. The same tests are also discussed by Magnusson (99) who reports that the optimum quantity sprayed is 320,000 to 430,000 gal/yr/acre. With this loading the phosphorus and potassium content of the soil increased some, but apparently not enough to do any harm. Grass output was increased by 50 to 100 per cent and by adding some nitrogen the output could be further increased. The character of the grass was not changed. However, by using 910,000 gal/yr/acre grass was killed off in spots. The mineral content of the grass was slightly changed toward higher sodium chloride and lower potassium and magnesium. Cattle fed on the grass remained perfectly healthy. By overloading the field, the ground became soggy and the animals muddy. Spraying was not practiced in the winter when direct discharge to the watercourses was permitted. Installation costs were relatively high because of the use of large collection basins capable of holding a full day's waste during the flush season. It appears that in some countries (Holland, New Zealand, etc.), the trend is to use large reservoirs in order to even out the load and cut power demand by irrigating when the milk plant is not in operation. In other countries (U.S.A., Germany, Sweden, etc.), small flow-equalizing tanks are preferred so that

the waste can be applied as fresh as possible, the costs of construction and cleaning labor reduced, and the possibilities of odor trouble minimized.

Based on the work done at the Eastern Regional Laboratory and Pennsylvania State University, the Agricultural Research Service of the U. S. Dept. of Agriculture (139) has issued a revised summarizing report on the treatment of dairy waste by aeration (modified activated sludge) covering theory and detailed recommendations for installation and operation of batch-type plants. Continuous operation is also mentioned but the low-cost compact plants of this type are not discussed. McKinney and Schwinn (107) describe such a plant designed to treat 8,700 gpd of a combination restaurant and ice cream plant waste averaging a BOD concentration of 550 mg/l or 40 lb/day. The treatment plant consists of a single concrete basin 10 ft × 20 ft × 10 ft deep. The aeration section with 35-hr retention is separated from the settling compartment by a sloping baffle. Air is supplied by a 90-cfm blower through perforated steel diffuser pipes. An air lift returns sludge to the aeration side. The BOD removal is 90 to 95 per cent. No sludge is drawn off, but at times some excess solids pass out with the effluent. Presumably this is not objectionable since the aeration time is so long that any excess solids will have very low BOD.

Thom and Glowacki (159) report from Poland on laboratory and pilot-plant studies of the activated sludge process treating dairy wastes. They investigated the effect of pH, temperature, solids content, method of aeration, etc. They obtained 92-per cent reduction within 24 hr even with strong wastes. Ingram (81) investigated six dairy waste disposal plants in New York. Two of them were trickling filters and two were lagoons with circulation. One of the aeration plants was of the batch type (Copiaque, L. I.) using suction jets. Poor results were attributed to high pH (10.9 to 11.95) in the influent. It is not explained why this could not be corrected immediately. The other aeration plant (Horseheads, N. Y.) was of the continuous type, using pressure jet aeration. At the time of the survey, this plant showed only 64.4-per cent BOD reduction in spite of the fact that the BOD loading was only 124 lb/day in a plant that is designed for 320 lb/day. Apparently something that happened just prior to the survey, such as a discharge of strong caustic, had something to do with the poor results.

Gault (62) reports on the proper handling of a BOD shock load from dairy products accidentally discharged to a municipal activated sludge plant (Delta, Ohio, 2,400 population). When the accident occurred, the milk plant notified the municipal plant, which immediately increased the return sludge from 43 to 63 per cent and increased the air supply to 2 cu ft/gal. Although the DO in the effluent dropped temporarily from 2.6 to 0.3 mg/l, it was back to 2.2 mg/l in 5 days.

Viehl (165) describes a ring-shaped canal type of activated sludge plant, aerated with a Kafig brush in Germany. The canal is 3.3 ft deep and 15 ft wide at the top and has a useful capacity of 80,000 gal. It was treating the waste from a village of 1,000 people plus a slaughterhouse and a milk plant (butter and cheese). The overflow passed into a settling basin. The raw waste flow was equalized to avoid shock loads on the system. Due to the long aeration time, purification was very good in spite of low oxygen content. Excess sludge was removed periodically to a thickener. The partially dewatered sludge was then spread on the fields. Magnusson (99) describes two similar experimental installations in Holland, one of which had been in operation since 1955. The oxidation ring canal was 3.3 ft wide, 3.3 ft deep, and 100 ft long, giving a capacity of 7,500 gal. A brush aerator was used

for aeration and agitation. The raw waste entered just before the brush. The outlet was on the side of the ring canal opposite to where the baffles were placed in such a way that the sludge was retained in the system. Average BOD removal for one year's operation was over 97 per cent, but the loading was only 8,700 to 13,000 gpd and contained 16 to 25 lb BOD/day. The sludge had excellent settling properties. At the time of the report, no excess sludge had been removed. There were some difficulties with sludge settling in the turns of the canal because of insufficient velocity to keep the sludge in suspension. This was scraped loose once a day. In the second installation this difficulty was eliminated by using wider curves and higher velocity (0.2 fps). The new ring canal was about 10 ft wide, 4 ft deep, and 210 ft long, giving a capacity of 64,000 gal. Aeration was provided with a Kessener brush. The immersed depth of the brush varied since this was not a continuous operation. The aerator was stopped and the sludge allowed to settle before the effluent was withdrawn. The average BOD load was 114 lb/day. In this installation the sludge did not settle as well as in the first one. Also the sludge volume was increasing and would ultimately have to be reduced. The BOD removal was 98 per cent. The author warns that in colder climates freezing difficulties might be encountered.

A 1957 report by Morgan and Baumann (115) on two successful high rate recirculating trickling filters (one single-stage, the other two-stage) was missed in previous annual surveys. The results obtained were in line with what has been reported elsewhere for this type plant.

Ingram (81) described two recirculating trickling filters, one operating as a single-stage batch process (East Aurora, N. Y.) with a 3,200-gal holding tank and a square rock filter, with 86.5 sq ft of surface and 6 ft deep. The liquid was pumped at 30 gpm or 21.8 mgd/acre. Since this bottling plant was operating only every other day, the waste was recirculated from 42 to 45 hr before the contents of the holding tank were emptied without settling. A grab sample from the effluent showed 144 mg/l BOD. There were no sludge or odor problems and the treatment was apparently adequate under prevailing conditions. In a later report Ingram (82) describes pilot-plant experiments at another milk plant (Honeoye Falls, N. Y.) with a unit consisting of two columns, each with 4 sections of 2-ft ID asbestos-cement pipe resting on ½-in. steel grates. The sections were joined tightly to each other and air was blown in under each section (50 cfm altogether). The filling material was 2½-in. stone and the depth 2½ ft in each section. There were provisions for varying liquid and air flow and recirculation rates. Results suggest that with raw waste BOD loadings of 20,000 to 30,000 lb/day/acre-ft (about 12 to 18 lb/cu yd) removal of about ⅔ of the BOD can be expected. Recirculation appeared to be of no benefit except to keep the filter wet when there was no waste to be treated. Because of various experimental difficulties, no runs were really continuous and results fluctuated quite widely.

Schulze (147) reports on experiments with a trickling filter made of vertically suspended wire grids and fed with city waste fortified with increasing amounts of whey. He found at constant hydraulic loads that the efficiency of the unit remained constant for organic loads up to 11 lb BOD/cu yd and the fraction of the BOD remaining was proportional to the two-thirds power of the hydraulic load. He also presents an equation relating efficiency to depth, hydraulic load, and temperature. It appears theoretically that recirculation does not improve the quality of the final effluent although in practice it may be beneficial due to sec-

ondary factors such as more equalized load, better distribution, and reduced clogging.

Wheatland (170) discusses the entire dairy waste problem, showing the usual strong British preference for the alternating double trickling filter over recirculating high-rate trickling filters and modified activated sludge units. Relatively large flow equalization and primary settling tanks and two large humus tanks are used. As the BOD loading is kept down to 0.32 to 0.48 lb/day/cu yd the effluents are excellent. First cost of such an installation is relatively high and it takes a full-time employee to operate and keep the plant clean but power costs are low. In this paper which carried discussions, Baumann made the surprising statement that he visited 40 to 50 dairy waste treatment plants in the United States and found none that was satisfactory except those using trickling filters.

Maloney *et al.* (103) studied the effect of whey wastes on stabilization ponds in California. The system has primary clarification and separate sludge digestion with sludge drying beds. Three ponds covering 50 acres total are operated in parallel taking care of 18,000 population with a sewage flow of 1.5 to 2 mgd. The sewage contained sulfides and about 3,000 mg/l sodium chloride. The city water had 280 mg/l sulfate. Trouble was experienced with hydrogen sulfide odor and poor performance of the ponds. After much testing it was concluded that the trouble was, at least indirectly, due to the annual discharge of 11.5 million lb of cottage cheese whey by a local dairy. Even so, the ponds were only receiving 50 to 70 lb BOD/day/acre but over one-half of this load was due to the whey. When the dairy waste was diverted elsewhere, the ponds improved. The addition of nitrate helped but did not cure the trouble. Since large amounts of whey are tolerated by other oxidation ponds, it is probable that the difficulty was due to a combination of whey and high sulfate content in the water.

As mentioned above, Ingram (81) investigated six dairy waste disposal plants, two of which had lagoon systems. One plant (East Aurora, N. Y.) was making cheddar cheese daily from 50,000 to 100,000 lb of milk and making bottled milk and ice cream from about 12,000 lb of milk. The whey was first sent to a storage tank to settle out the solids, then to a separator to remove some residual fat, and then discharged to a disposal well. Any whey that the well did not absorb went to the lagoons. All other washings and rinsings were also collected in a settling tank (which was cleaned once a week and the sediment hauled away) and then pumped to the lagoon. No actual data were available about how much whey went each way but it was estimated that 11,000 gpd whey and 12,000 gpd of other wastes were discharged to the lagoons. At the beginning of the test, two lagoons were in use; at the end a third one had been added. A pump was bringing 200 to 300 gpm of liquid in lagoon 2 back to lagoon 1 through a fire nozzle. The BOD of the mixture fed to lagoon 1 was 4,500 mg/l. Composite samples from the lagoons did not indicate any BOD reduction, but that could have been due to much heavier loading before the test started. Spray irrigation had also been tried unsuccessfully at this plant. Obviously the sizes (not indicated) of either system were quite insufficient for the load. The other plant (Arkport) made ice cream mix, sour cream, buttermilk, condensed milk, and powder. The milk received averaged 359,000 lb daily for the year and during the flush season was about double that amount. The treatment plant consisted of 6 lagoons separated by low dams, 1 ft thick, 2 ft deep, and 28 ft wide (20-ft weir overflow). There were 4 circulating pumps, each 500 gpm, 7½ hp, each of which took waste from below one dam and sprayed it over the lagoon above.

Total area of the lagoons (735 × 30 ft) was about ½ acre. Maximum flow was 325 gpm or 172,000 gpd. Raw BOD in composite daily samples was 91 to 870 mg/l. The total daily BOD load varied from 175 to 1,700 lb/day. Final BOD at the outlet of the last lagoon was 0 to 200 mg/l. The bottoms of the lagoons were scraped at irregular intervals. The sludge appeared to be well digested and drainable and did not have any objectionable odor; however, there was appreciable odor from the sprays. Obviously, there was insufficient area for lagoon treatment and insufficient aeration and tank capacity for an aeration plant. Still the plant did remove a great deal of BOD and the receiving stream was in excellent condition.

Much development work is being done toward new uses of whey by purification, mixing, and fermentation. While whey utilization frequently becomes a very important part of dairy waste disposal, it must still be considered as by-products utilization rather than waste disposal. Many references concerning this subject have been omitted. Some are listed below under additional references.

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Meat Packing and Poultry Processing Wastes

Four years of operating data on a 2-stage lagoon system (anaerobic-aerobic) treating meat packing wastes at Moultrie, Georgia, reported anonymously (13) and by Sollo (151), show BOD of the raw waste 879 to 390 mg/l, anaerobic effluent 55 to 454 mg/l, and final (aerobic) effluent 40 to 127 mg/l. These are semi-annual averages and were affected by some drop in efficiency when the anaerobic pond temperature dropped below 75°F. A second anaerobic pond at Wilson, North Carolina, has been equipped with direct steam heating. The anaerobic lagoon is 14 ft deep at the center, with a total detention of 6 days. The 19.2-acre aerobic lagoon is 3 ft deep with a detention period of 19 days. Sludge is recirculated from the bottom of the anaerobic pond to the influent, and the final effluent is recirculated to the influent end of the aerobic lagoon at a rate of about 2 : 1.

The first three months of operating data on the completed "anaerobic contact" plant treating meat packing wastes at Albert Lea, Minnesota (12), show the BOD of the anaerobic plant effluent averaged 123 mg/l and the polishing oxidation lagoon effluent at 19 mg/l, for an over-all reduction of 98.5 per cent. The average digester BOD loading was 0.124 lb/day/cu ft.

Pilot-scale studies of alternative methods for sludge separation in the anaerobic contact process, treating meat packing wastes, reported by Steffen and Bedker (153), showed that vacuum degasification preceding sedimentation was most economical and efficient for the Albert Lea, Minnesota, plant where the studies were made. Degasification by aeration was also successful but sludge concentration was not improved.

About 0.1 cu ft of air was required per gallon of mixed liquor (digester effluent) at 8- to 10-min detention in the aerator. Practical considerations, such as additional power requirements, safety hazards in releasing methane into the atmosphere, possible odor problems, and the loss of the released methane as a source of additional heat all contributed to the final decision. Parallel versus series operations of two separators (sedimentation tanks) following vacuum degasifiers yielded return sludge at 16,000 mg/l suspended solids in parallel operation, versus 14,600 mg/l from separator No. 1 and 12,000 mg/l from No. 2. A study of pressurized air flotation as a solids recovery method yielded effluents of 200 to 220 mg/l at or below solids loadings of 88 lb/day/sq ft of tank surface. Better effluents were obtained by the other methods studied but this method may prove useful when the anaerobic contact process is used as pretreatment before discharge to a conventional municipal plant.

A detailed in-plant waste-saving study at a large meat packing plant (9) resulted in the following modifications: (*a*) discharge of hasher waters to a separate interceptor with 70-min detention, yielding a 25-per cent increase in grease recovery; (*b*) recirculating a portion of the effluent from the principal interceptors to the hasher sprays, yielding 750,000 gpd flow reduction; (*c*) recirculating the effluent from vibrating screens (used to concentrate bottom sludge from grease interceptors) to the influent end of the grease interceptors increasing grease recovery an additional 14 lb per ton of live weight kill.

Fermentation, Chemical, and Pharmaceutical Wastes

Howe (79) reviewed current status of pharmaceutical waste treatment, including those from antibiotic, steroid, vitamin, chemical, and antitoxin production, and briefly described 10 waste treatment facilities in the industry.

Ghose and Rao (63) found that anaerobic fermentation periods of less than three weeks were sufficient for decomposition of distillery wastes resulting from cane sugar molasses alcohol fermentation.

Eckenfelder and Bueltman (53) studied brewery waste bio-oxidation and provided design parameters for the oxidation and secondary sedimentation process steps. At BOD levels exceeding 150 mg/l, oxygen utilization rates of 100 mg/l/min/1,000 mg/l sludge solids were measured. Free settling overflow rates of 1,100 to 2,500 gpd/sq ft were observed along with compaction loadings of 0.03 to 0.05 sq ft/day/lb for production of 1-per cent consistency secondary underflow.

Howe and Nicoles (80) described disposal of pathogenic, animal, antisera and antitoxin, and toxic chemical wastes from veterinary and plant science research facilities. Pathogenic wastes are heat-sterilized, while toxic chromate and phenolic wastes receive conventional redox-type treatment before mixing with remaining effluents for sedimentation, sludge digestion, and trickling filter treatment.

Benkowitz (24) patented a process for purification of Frasch process sulfur mining effluents involving aeration in presence of scrap iron to convert sulfur compounds to ferrous sulfide, followed by further oxidation to ferric oxide and elemental sulfur. The resultant sludge is settled and recycled to provide further reaction surface.

Specht (152) reported on a two-stage process for removal of phosphate and fluoride from superphosphate production effluents containing 5,000 and 1,700 mg/l of each, respectively. Successive lime neutralization to 3.5 and 7.0 with 2-stage sedimentation produced an effluent containing 0 and 5 mg/l, respectively, of phosphate and fluoride.

Baffa (22) outlined batch and con-

tinuous flow neutralization basin design using four-compartment layout and pH controlled lime slurry feed. Recommended basin linings, construction materials, and slurry preparation methods were reviewed as well.

O'Shana (130) noted how technological changes to powderless etching had adversely affected conventional limestone neutralization of photoengraving wastes by causing oil coating of the marble chips. Use of soda ash in place of limestone was recommended to overcome this difficulty.

Tatlock (158) described development and initial operation of an acidic and fatty waste treatment system consisting of lime neutralization, sedimentation, and sludge thickening with final disposal by hauling wet sludge to land fill. Treatment rendered effluent suitable for discharge into the Cincinnati sewer system without surcharge payment.

Hickerson and McMahon (76) reported on preliminary greenhouse studies of irrigation disposal of lime lee and water column effluents from methanol and acetic acid production, respectively, by wood distillation. Neutralization with limestone and addition of mineral fertilizers permitted disposal of 0.05 in./day of 6,000-mg/l BOD effluent over clover and fescue cover vegetation.

Gill *et al.* (65) reviewed the receiving water requirements established for a tetraethyl lead production unit which specified a lead content of less than 0.05 mg/l, 0.5 mile from the outfall, and an increase of no more than 0.1 mg/l per year in the bottom sediment on a 100-ft radius from the outfall. Ferrous sulfate flocculation, neutralization, and sedimentation are employed for treatment of the effluent containing 18 mg/l-Pb and 600-mg/l BOD, followed by discharge through a multiport diffuser outfall.

Eustance (57) described clariflocculation of 20-mgd photo industry waste followed by lime conditioned sludge filtration to 30-per cent solids at a filter loading of 2 lb/hr/sq ft. A multiple outlet diffuser is used to provide effective mixing 300 ft from shore in 20-ft water depth.

Wilson (172) mentioned steps taken to control losses of ammonia and nitrate nitrogen from a nitrogen fertilizer plant, including monoethanolamine substitution for aqua ammonia in the hydrogen purification stage.

Malaney (101) studied the ability of aniline acclimatized activated sludge to oxidize various aniline derivatives, such as phenylene diamine, toluidine, aminophenol, chloroaniline and nitroaniline and nitrobenzene, amino benzene-sulfonic acid, alkylamines, alkylanilines and benzenes, etc. The aniline acclimatized sludge was shown to have a wide range of metabolic activity, although significant differences in oxidizability were noted.

Ludzack and Ettinger (96) summarized available data regarding resistance to aerobic biochemical stabilization for several hundred organic compounds, including hydrocarbons, alcohols, phenolics, aldehydes, acids, esters, ethers, ketones, amino acids, nitrogen compounds, vinyls, polyoxy, and surface active agents. Acclimation and cross-acclimation techniques and findings were reviewed and some generalizations regarding the relation between structure and biochemical availability presented.

Giebler (64) discussed pretreatment required for denitro-o-cresol and hexachlorocyclohexane effluents from insecticide production to prevent interference with standard sewage treatment processes and to eliminate objectionable color.

A description of an activated sludge installation for parathion waste treatment was described (5). Reduction in phenolic content of 90 to 98 per cent and 85- to 90-per cent BOD reduction are obtained at conventional loadings. Oxidation is preceded by limestone neutralization and equalization.

Mills (111) reported on pilot-scale

trickling filter and activated sludge treatment studies on 2, 4-D production effluents, and found dichlorophenol to be less readily oxidized than phenol itself. Deep well disposal of insecticide production effluents was begun at the Rocky Mountain Arsenal (8). Colloidal particles as small as 0.5 μ are removed before injection into pre-Cambrian formation at 11,400-ft depth. Geologic investigations preceding process selection are summarized.

Neas (122) described treatment of viscose rayon wastes, including lime neutralization to pH 8 for zinc removal, clarification at 3,000 gpd/sq ft, and difficult filtration of underflow to 15-per cent solids at 0.5 lb/hr/sq ft. Further studies are being directed at improved sludge dewatering.

Meinhold and Mandele (110) reported on submerged combustion treatment for removal of cyclohexane and toluene from organometallic processing effluents. Concentrated effluent then is neutralized and pressure filtered prior to lagooning and final discharge.

Sereu (148) described a new incineration unit rated to handle 140 million Btu/hr of liquid tars and solid refuse, including 500,000 gal per month of still residues, waste solvents, and contaminated products.

Coal Wastes

Raleigh (142) reported that Orsanco and the coal mining industry have reached an agreement on acid drainage controls. Sulfuritic material should be: (*a*) sized to eliminate large aggregates, (*b*) stored at a site that would minimize ground water flow through the refuse, (*c*) compacted thoroughly to minimize air flow, and (*d*) covered with vegetated soil to eliminate surface erosion. Pollution abatement has been achieved at coal stripping operations by diversion of surface water; covering coal measures not recoverable; and sealing exposed faces by backfilling. Such procedures are included in mining regulations in Pennsylvania and Ohio. Hert (75) described a weekly sampling program adopted by an Indiana coal company as a check on the effects of the operation on receiving streams. Analytical data show that pollution from mine drainage can be controlled by proper planning prior to opening a mine and by taking suitable steps when a mine is closed or abandoned. The principal steps are diversion of surface water and covering compacted sulfuritic material. Fine coal from an anthracite washery is being recovered from a strip-mine lake by a floating dredge at McAdoo, Pa. (7). The pit was formerly used as a disposal basin for the washery. The machine produces 150 cu yd/hr of material that is mostly <200 mesh; it is especially valuable for boilers using pulverized fuel.

By-Product Coke Wastes

Nenich *et al.* (123) described the operation of a biological dephenolization plant. They pointed out that successful operation required an influent of constant flow and composition, absence of tars and oils, presence of some phosphorus, temperature of 25 to 35°C, total ammonia below 2 g/l, and pH 7.2 to 7.9. An influent containing 3 g/l of oil disrupted plant operation, and two oil separators were necessary. The plant is operating at a feed rate of 18 cu m/hr with 1,140 mg/l of phenols, an air rate of 2,500 to 3,500 cu m/hr, and 0.5 kg superphosphate per cu m of influent. The 99.7-per cent dephenolized effluent is used to quench coke. No information is given about the biological medium itself. Bringmann and Schroder (32) found that only 20 per cent of the phenols in wastewater from a plastics plant could be dissimilated in an activated sludge plant treating domestic sewage, and extraction processes were similarly unsatisfactory. Bringmann had shown that phenols up to 1,600 mg/l could be decomposed continuously by a culture of *Nocardia* in

an activated sludge process. Cyanide up to 60 mg/l did not interfere. A pure culture of *Nocardia* was developed in a synthetic inorganic medium and used to inoculate a 3-cu m pilot activated sludge plant in which the organisms were acclimated to increasing amounts of pure phenol. This plant destroyed 99 per cent of the added phenol at a concentration of 500 mg/l. A 400-cu m plant was then built and the organisms were conditioned with sodium phenolate. There were two waste streams from the plastics plant, one strongly basic and one quite acid. The streams were blended to provide a mixed liquor at pH 8.7 and an average phenol content of 10,000 mg/l. An equilibrium value of 300 to 400 mg/l developed in the aeration tank. The discharge from the secondary settling basin contained about 100 mg/l phenol, corresponding to a 99-per cent reduction. Dissimilation of phenol ranged from 0.6 to 0.9 kg/cu m of aeration capacity, equivalent to 240 to 360 kg/day.

Pankhurst (135) has made laboratory and pilot-plant studies of biological oxidation of gas liquor with pure and mixed bacterial cultures. He found that mixed cultures grown on the spent liquor readily oxidized phenol, o-, m-, and p-cresols, catechol, 3- and 4-methyl catechol, resorcinol, and 2- and 4-methyl resorcinol; quinol, pyrogallol, and phloroglucinol were more resistant. Oxidation was most efficient at 30°C and pH 6.5 to 7.8. Pure cultures of five phenol-oxidizing organisms were isolated; copper concentration above 1 mg/l inhibited both growth and phenol oxidation of one of these. Mixed cultures grown in an ammonium thiocyanate medium originally inoculated with *Thiobacillus thiocyanoxidans* oxidized sodium and potassium thiocyanates; thiocyanate oxidation was inhibited by chlorides above 5,000 mg/l (but adaptation to 15,000 mg/l was possible) and by phenol above 300 mg/l. Mixed cultures grown on sodium thiosulfate oxidized sodium tri- and tetrathionate, potassium penta- and hexathionate, and potassium and ammonium thiocyanate. It was concluded that a two-stage process, with the first for oxidation of phenols and the second for thiocyanate, would be best for complete treatment of gas liquor. Badger and Jackman (21) extracted monohydric phenols from gas liquor with tar oil prior to biological oxidation. They concluded that extraction, which would not remove polyhydric phenols and thiocyanates, would reduce oxygen requirements appreciably but would not result in a decrease in the size of aeration tanks.

It has been reported by Cotton (43) that high gas-liquor loadings reduce the efficiency of an activated sludge plant, owing to competition for oxygen by ammonia and synthetic detergents. Inadequate oxidation may affect activated sludge density and operation of final settling tanks. Graves (69) found that it is practical to oxidize phenols in wastewater from an oil refinery in an Imhoff tank-trickling filter plant treating domestic sewage. The wastewater flows to the sanitary sewage and the treatment plant reduces the phenols about 88 per cent, to an average of 1.8 mg/l. It has been possible to destroy some 110 lb of phenolics per day at a flow rate of 70 gpm without affecting the oxidation capacity of the sewage treatment plant. Ludzack and Ettinger (96) tabulated data from the literature on the aerobic dissimilation of a large number of compounds. Techniques ranged from activated sludge to natural river water. Oxidation rates varied widely. Benzene and its CH derivatives were oxidized only slightly in 14 days, but the presence of an OH group increased the oxidation rate at least 10-fold. In general, the latter group was broken down much more rapidly in river water than in other substrates. With suitable acclimatization, cyanides can be oxidized almost completely on a trickling filter.

Phenols have long been blamed for malflavored drinking water in steelmaking districts. Kinney (89) reported a field study showing that limiting phenol concentrations will not insure protection of a water supply against tastes and odors. It was found that increasing a normal discharge of 100 lb of phenol per day to 3,600 lb/day above a waterworks intake caused no trouble. Taste and odor incidents were traced to cleanout of organics low in phenol but high in odor intensity and chlorine demand.

Reid *et al.* (143) have studied destruction of phenols on rotating drums, by biological filtration, and by the activated sludge process. They found that biological slime on a rotating drum can handle phenol concentrations up to 7,500 mg/l, whereas trickling filters could handle 100 mg/l and activated sludge 500 mg/l. Dierichs and Jaehn (49) investigated adsorption of catechol and its homologs on coke powder and the catalytic conversion of phenols to water-insoluble polymers. Their results indicated that adsorptive purification of wastewater, from which phenols have been incompletely removed, can be attained economically with coke or coal dust.

Barker and Hollingsworth (23) reported on an extensive study of analytical methods for determination of monohydric and dihydric phenols. The improvements provide greater accuracy than previously possible for the high concentrations that occur in gas liquors. Faingol'd and Senkovskaya (58) proposed a method for determining naphthalene in wastewater from coke plants. The naphthalene is separated by filtration and distilled at 80 to 85°C into a solution of picric acid. When distillation is complete, the picric acid is back titrated with 0.02 N sodium hydroxide.

Petroleum Processing Wastes

Biological treatment of refinery wastes continues to increase in areas where receiving water quality must be maintained high because of subsequent uses. Activated sludge was shown to be effective in removing 60 to 70 per cent of the synthetic detergents present in one refinery wastewater (145). Jung (85) found that treatment efficiencies were improved when an aerated iron hydroxide sludge preceded a typical activated sludge unit rather than conventional iron sulfate-lime coagulation. An animal-free growth developed in the iron hydroxide sludge. He failed, however, to compare removals against two-stage activated sludge treatment which this system closely approximates.

Lagooning is receiving more emphasis in areas where adequate temperature and land area are available. Van Heuvelen *et al.* (164) reviewed the over-all design, construction, and operation of lagoons which included applications for refinery wastes. Waste stabilization ponds were used in conjunction with activated sludge as reported by Gilliam and Anderegg (66).

Air flotation, a heretofore little used method, is receiving more attention by refiners. Roth *et al.* report on an 8.8-mgd plant (144) to be completed in 1961 which will be the largest installation of this process in the petroleum refining industry. Pilot plant data indicate removal efficiencies of 90 to 95 per cent for oil, 52 per cent for COD, and 74 per cent for suspended solids. Sherwood (149) reported 80-per cent oil removal by flotation. A theoretical discussion of air flotation based on Stokes Law with applications to oil removal was given by Vrablik (167).

Emulsified oil has always been troublesome to refiners. New information shedding light on the influence of various types of solid particles in helping stabilize emulsions was presented by Mitkalev and Kozorezov (112). One plant reported that emulsion breaking consists of acid treating (51). Emel'yanov (55) reported effluent oil reductions from 86 to 265 mg/l to 19 to 57 mg/l by separate col-

lection, treatment, and disposal of emulsion sources. Coke and/or coal was shown to be capable of reducing oil levels to <5 mg/l (2). Coke worked equally well at both high and low influent oil levels.

Treatment and disposal methods for wastewater containing phenols have been studied extensively because phenolic compounds are considered a source of taste and odor problems in domestic water supplies. Biological systems such as activated sludge and trickling filters, are frequently used to reduce the phenolic content to acceptable discharge levels. Graves (70) reports an 88-per cent phenol reduction in an Imhoff tank, trickling filter, and secondary settling sewage treatment systems. The effluent contained less than 2 mg/l. High phenol levels and large variations in concentration, however, may be toxic to the biological system. Thus laboratory and pilot plant evaluations of other treatment methods are frequently encountered. The ion exclusion method (48) has shown promise in concentrating petrochemical wastes containing phenolics for ultimate recovery of the organic material but data were not presented for an economic comparison with other methods. A 99.9-per cent phenol recovery from a waste stream containing 5,000 mg/l phenol has been obtained by plant-scale organic solvent extractions using a continuous treatment method (72). Other efficient extraction systems include (83) the use of cottonseed oil, activated carbon, and chemically treated sawdust (100) and 10-per cent butyl acetate solution which gave 97-per cent removal of a 6.88 g/l phenol waste (16). McRae *et al.* (109) reported on a system being used to keep accidental spills or leaks of large quantities of phenol from being discharged at high concentrations. A continuous phenol analyzer was developed and is used to monitor the clean cooling water streams being discharged without treatment. When the phenol concentration exceeds a predetermined level, this stream is diverted to impounding tanks and it is then burned in phenolic wastewater incinerators. In this plant, incineration is more economical than flue-gas stripping and biological oxidation.

Bramer (31) and Jusmann (86) have reviewed oil pollution problems and ways in which the wastes are reduced or treated. Water conservation by in-plant processing changes are being used to reduce the quantity of wastewater (19) (31) (33). Still another refiner conserves water by using the effluent from an activated sludge sewage treatment plant as raw water feed to their supply treatment plants (16). Several specific waste treatment schemes for refineries were reported (14) (33) (106) (146) (162) (163). Most schemes contain several treatment steps which differ from one plant to the next. The wide variation in the wastewater treatment methods employed are generally based on the characteristics of the receiving stream or lake and the subsequent downstream use of the same water. Consequently, more emphasis is being placed on adequate stream and wastewater surveys as a part in planning waste treatment facilities and/or in-plant changes to reduce the wastewater flow (44). Cooperative industry-government programs to determine pollution control needs are illustrated by McRae (108).

The collection, treatment, and injection of oil well brines into producing reservoirs to increase crude oil production were reviewed for a large east Texas oil field (116). Chemical treatment and control of biological activity are needed to prevent plugging of the pores in the producing rock. Again, in-plant operations can influence the degree of treatment needed. In Russia (136) it was indicated that automatic shutoffs on water drains and good maintenance of the mechanical equipment resulted in a large reduction in the oil content of oil-well brines.

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Pickling and Acid Wastes

A process for treating pickle liquor was patented in England (132). The liquor, with pH adjusted to 5 or higher, is treated in the presence of ammonia with a gas containing 8- to 25-per cent CO_2, less than 4-per cent O_2, and less than 2-per cent SO_2, by volume. The contact gas must be free from cyanides and sulfides. The iron is precipitated as ferrous carbonate; this is filtered off and ammonium sulfate is recovered from the filtrate. Thomsen (160) patented a somewhat similar process in which a slight excess of an iron-free ammonium sulfate solution containing ammonia and CO_2 is added to pickle liquor to precipitate the iron as ferrous carbonate. The precipitate is filtered off and the filtrate is divided into two portions; one portion is recycled to the process, and ammonium sulfate is crystallized from the other. A much more complex process was patented by Collin *et al.* (41). This is a 5-stage, cyclic process which accomplishes an end similar to the above processes; it differs from them in that it utilizes raw coke oven gas as a source of ammonia.

Dembitz (47) described a process claimed to be profitable for pickle liquor reclamation. Ferrous sulfate monohydrate is crystallized from the spent liquor by concentration in a multiple effect evaporator. The sulfate is roasted to iron oxide and SO_2; the latter is converted to 98-per cent sulfuric acid in a contact plant. It is estimated that the process will return a 10-per cent profit on the capital investment. There are many processes like this one, but none has yet been found to operate at a profit. An electrolytic process (4) was developed on a pilot scale for recovery of acid and iron from sulfate pickle liquor. The inefficiency of electrolytic deposition of iron from acid solution is overcome by separating the iron as a mercury amalgam in a primary cell where acid is generated from ferrous sulfate. The iron is plated out in a secondary cell where the pH can be controlled. Excluding amortization, the process is said to break even in terms of Austrian costs. Lewis and Tye (94) described experimental studies of electrodialysis of pickle liquor which provides a basis for computing the effect of power cost on treatment cost, for operating procedure, for electrode-membrane distances, and for practical compositions of influent and effluent streams. Several investigations of electrodialytic processes in the United States have indicated that they are feasible but economically unattractive.

Wastes from pickling and brightening operations at a tube mill are treated for recovery of copper, zinc, and chromium in a process described by Bethel (25) and Bethel *et al.* (26). Weak rinses are aerated in an earthen basin to equalize composition. Strong pickling and dichromate solutions are stored

in tanks. Hexavalent chromium is reduced by treatment with sodium bisulfite. The strong wastes are combined with the rinse waters and mixed in a tank where lime is added to raise the pH to 9.5. The sludge containing the metal hydroxides is stored in a lagoon. Moran (114) stressed the advantages of using phosphoric acid for pickling steel. The acid can be regenerated by ion exchange. No costs are given.

Plating and Cyanide Wastes

The consumption of water by the plating industry, although not as great as for some industries, is appreciable and the loss of chemicals in plating rinse wastewater can be costly. At some point, depending primarily on geography, recovery of chemicals and water savings justify water reuse and chemical recovery. This situation is developing in a number of areas as revealed by the 1960 literature. A rather comprehensive study (74) of the extent of nickel and chromium losses in England also includes recommendations for control of such losses. The study was based on data from 42 firms. Consumption of anodes and salts is given for the plants. Salts added as the percentage of anodes consumed ranged from 1 to 85 per cent. The amount of salts added is assumed to represent the nickel loss and to be equivalent to an increase of about 11 per cent of the nickel deposited (2,580 tons of nickel anodes). Only 13 per cent of the chromic acid is deposited on the work, 67 per cent being lost by drag-out and 20 per cent by spray formation. A third section discusses water consumption (25 to 1,875 gal/lb of nickel) and means for reducing the amount used. The results of water management applied to metal finishing as well as all operations at a large appliance (59) facility was reported to present a saving of about $250,000 per year. The reuse of water at the plant of a washing machine manufacturer is described (78) and the water consumption at a well-designed data-processing machine manufacturing plant (73) was reported on about one quarter the amount originally expected.

A Russian group has been concerned with the treatment of cyanide-bearing wastes. In one paper Lur'e and Panova (98) claimed that the extent of purification can be controlled by the simple procedure of maintaining 3 to 5 mg/l of chlorine in the effluent. If this condition is maintained, cyanide and complex cyanides such as copper and zinc will be absent, although the very stable cyanide complexes such as ferricyanide may be present. A second paper (97) discusses the economics of the electrochemical treatment of wastes containing 15 to 230 mg/l of cyanide. Diaphragm cells operated at room temperature at 1 to 6 amp/sq dm in preliminary runs with platinum, stainless steel, nickel, graphite, and magnetite showed promise. At 0.1 to 0.5 amp/sq dm the current efficiency was increased 30 to 40 per cent, reducing the energy consumption to 0.01 to 0.02 kwhr/g of cyanide. The presence of chloride ions increased the current efficiency to 60 to 80 per cent, lowering the cost to 0.007 to 0.01 kwhr/g of cyanide, and decreased the electrolysis time to 3 to 3½ hrs.

Canan (39) proposes the use of flue gases to treat chromium wastes instead of metabisulfite. Sulfur dioxide in powerhouse stack gases is used to reduce the hexavalent chromium by circulating the gases to a scrubber by means of a low pressure blower. About 20,000 cu ft of flue gas at 250°F and 5 in. pressure are required for each pound of chromic acid. The reduction process is followed by a precipitation step by lime or caustic soda. Kaeding and Trielglaff (87) report that a quaternary amine-polystyrene resin will absorb dichromate ions in preference to chloride or sulfate ions at a pH of 2.2. The lower the pH the higher the

exchange capacity, but at a pH less than 3 the rate of oxidation of the resin is appreciable. The best over-all results are at a pH of 3.5 to 4.5 when the CrO_3 concentration is less than 800 mg/l. Wiedmann (171) reported the use of ion-exchange to remove metallic ions from chromium baths and rinses so that the drag-out rinse can be returned to the bath and thereby reduce pollution. Three resins were studied with respect to loading, breakthrough, and elution.

Erganian (56) reported on the effect of chromium plating wastes on a municipal treatment plant where a plating facility contributed half of the total sewage flow (0.87 mgd). Difficulty was experienced with the operation of the sewage plant on sewage containing 46 mg/l of chromium (total) and 5.4 mg/l of cyanide. The plating plant improved its housekeeping and reduced the surface tension of the chromium bath with the result that the chromium and cyanide are not now interfering with operation. Much analytical data are included in the paper.

In another instance (19) sewage plant operational problems developed as the result of a copper cyanide bath being dumped into the Grand Rapids sewer. A fluffy sludge resulted which required stopping the return sludge and continuing full flow through the aeration tanks until they were clear of activated floc.

Moulton and Hanna (117) by means of a laboratory-scale pilot plant, utilizing the activated sludge process and synthetic sewage on a continuous flow system, simulated conventional treatment and determined the effect of various ions on the process. At equilibrium shock dosages of nickel, copper, chromium, and cyanide were added for six-hour periods. There was a delay before the full effect of the toxic substance was realized. In the case of chromium, recovery occurs in about 48 hr up to 6 mg/l, but for higher concentrations recovery is slower. Studies involving CN–Ni at 7.5 mg/l along with Cr–Cu at 22.5 mg/l have been made. The resulting regression equation for these runs are being programmed on an IBM 650 computer to evaluate and correlate the direct and inner-effects of these four ions.

Livingstone (95) reviews the research work being carried out at the Stevenage Water Pollution Research Laboratory, including studies on the removal of cyanide by percolating filters. Presently the pilot plant can handle 90 mg/l of HCN at the rate of 700 gpd/cu yd for simple cyanides, but if mixed cyanides are present the HCN content must be reduced to 60 mg/l, the rate of flow to 150 gpd/cu yd and the pH should be 6.6. The temperature must be above 10°C.

In an activated sludge system wherein cyanide was the only source of carbon and nitrogen, Nesbitt *et al.* (124) found that more than 99 per cent of the cyanide was metabolized and the suspended solids maintained. About 98 per cent of the cyanide-carbon was converted to carbon dioxide and 75 to 90 per cent of the cyanide-nitrogen to ammonia, nitrate, and nitrite.

Anwar *et al.* (20) and Byerrum *et al.* (38) found no noticeable effect on rats of cadmium at 0.1, 0.5, 2.5, and 10 mg/l in drinking water, but the amount of cadmium in the liver and kidneys increased over the year in proportion to the quantity ingested. Some pathological changes were noted in the kidneys and livers of dogs subjected to drinking water containing 10 mg/l of cadmium. Dogs given water containing 1, 5, 10, 15, and 25 mg/l of chromate for a year showed no pathological changes. Up to the amount of 8 mg/l chromate appeared to be excreted. Studies on dogs extending over four years showed the chromium concentration to be greater in the liver than in the kidneys or spleen, but even at 25 mg/l no pathological changes were noted. Authors state that chromate in low concentration may even be neces-

sary for rats, which were found to have greater longevity if fed chromate.

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Pulp and Paper Mill Wastes

Stream Pollution

The 19 papers delivered at the Pulp, Paper and Paperboard Industrial Waste Conference (140) have been reproduced. They cover many phases of pulp and paper industry waste treatment including solids removal and disposal, BOD reduction, and the recovery of strong semichemical and sulfite liquors. Basic papers on the waste assimilative capacity of streams and aquatic biology are also included. A novel automatic ratio-controller system for effluent dilution in North Carolina is described by Bowers and Wells (30). The system protects the Catawba River which is highly variable in flow due to upstream hydroelectric uses.

A cooperative plant to biologically treat wastes from a paper mill at Luke, Md., and three adjoining communities, has recently been placed in operation (18). The activated sludge plant will treat 21 mgd, employs turbine aerators, and is designed for a 6.5-hr aeration period with a 40-per cent return sludge flow. A thickener and vacuum filter are being used to dewater waste sludge.

Sulfite

The major emphasis in the sulfite spent liquor field remains on chemical recovery and by-product processes. A thorough review (157) of the various recovery systems now in use or under development, including magnesia base, Sivola sodium-base, and Stora Kopparberg, indicates that rapid progress is being made in finding suitable and economically feasible processes.

There were reports of expansion of chemical by-product plants from several sulfite mills. New capacity was added at one plant (15) for products used in the manufacture of gypsum wallboard, dyestuffs, ceramics, refractory brick, and linoleum cement. In another plant the residues from the operation producing ethyl alcohol from spent liquor are being processed for various products used in adhesives, cement dispersion, oil well drillings, etc. (17).

The economics for furfural production from hardwood sulfite spent liquor are such as to make the process relatively unattractive unless some of the costs are charged to pollution abatement (137). Holderby and Moggio (77) discuss the factors involved in growing yeast in spent sulfite liquor. Operating results for a torula yeast plant show a 60-per cent reduction in the BOD of the liquor with a 90-per cent removal of the sugar fraction. The fermentor removal is 3.26 lb BOD/day/cu ft, while the dry yeast cell yield is 0.63 lb/lb BOD removed. A

process for the production of alcohol from spent liquor is claimed by Opderbeck *et al.* (128) which involves pH adjustment, addition of enzymes of fungi to bring about hydrolysis of the polysaccharides, yeast fermentation, and distillation of the alcohol. Cirillo *et al.* (40) report a fermentation process for producing edible mushroom mycelium using a liquid culture containing spent liquor.

Several reports regarding the effect of biologically treated spent liquor on slime growth and aquatic organisms were issued during the year. Cormack and Amberg (42) found a 75- to 93-per cent reduction in the weight of *Sphaerotilus natans* growth when treated liquor was used over untreated liquor in laboratory test channels. The treatment process to which the liquor was subjected was a modified activated sludge process at high temperatures (56°C). The process was capable of removing 68 per cent of the BOD in 12 hr at a loading of 2.4 lb BOD/day/cu ft. Marczek and Zielinski (105) made microscopic investigations of the fauna and flora in spent liquor under aeration. They conclude that biologically treated sulfite liquor can be safely discharged to rivers or lakes.

Where high dilution is available most of the year, storage of spent liquor during low flow periods and subsequent discharge at high flow has proven a satisfactory means of disposal. Buehler (36) discusses experience with a liquor lagoon which resulted in a 43-per cent reduction in downstream BOD levels. Woodworth (173) reports that by use of a temperature controlled diversion system for spent liquor from the blowpits, it has been possible for one plant to reduce the flow of liquor from 8.0 to 4.65 gal/lb of BOD pumped, thus conserving lagoon volume.

Kraft and Semichemical

The steps taken by an Australian paper mill to meet the stringent effluent disposal requirements of the Victoria Rivers and Water Supply Commission, are discussed by Stops and Agar (155). Laws and Burns (92) compare the use of diffusers and mechanical turbine aerators in the activated sludge plant at Luke, Maryland. The diffusion aerators originally used were found to be unsatisfactory due to scale buildup in the diffuser orifices. This was attributed to the high calcium content of the waste. A 40-per cent power saving has resulted from the substitution of turbine aerators for diffusers. The turbine aerators dissolve 1 lb of oxygen per 0.29 kwhr and no maintenance has been required in 7 months of operation.

The color of kraft effluents is not diminished by biological treatment. A new process (120) which integrates color removal with the kraft recovery process by using the lignin-containing lime sludge directly to recausticize green liquor, has been shown to be feasible. Color removals greater than 90 per cent and BOD removals of about 45 per cent have been obtained in the laboratory. A method for recovering lignin from alkaline bleach effluents is claimed by Doughty and Cook (52). The effluents are treated with alum to precipitate the chlorinated lignin and the precipitate recovered.

Othmer (131) claims a process for the recovery of acetic acid and other lower fatty acids from spent pulping liquors, including black liquor from the kraft and neutral sulfite semichemical processes. A method of concentrating spent pulping liquors so that they have a sufficiently high solids content to maintain combustion is claimed by Flynt and Suda (61). The method involves bringing the liquors from the pulp washers into direct contact with the hot flue gases obtained from the incineration of the concentrated liquor. It is claimed that the method is economical and suitable for use by smaller pulp mills.

Paper Mill

The search for the elusive completely "closed" white water system for paper mills continues. Gummels (71) reports on the Pista process and claims the process completely removes fibers and colloids from the white water, thus allowing full recirculation. The process consists of coagulation of the white water with ferric sulfate and lime, and sedimentation. It would appear that the dissolved solids buildup would eventually become a problem necessitating the introduction of fresh water at some point. The importance of good retention of stock on paper machine wires on subsequent saveall operation is discussed by Tifft (161). Proper use of retention aids may be a major factor in the control of white water losses. The Russel Separator is being used for recirculation of wash water and recovery of pulp fibers in the manufacture of molded-pulp articles (11). This screening apparatus works on the principle of gyratory vibration in a horizontal plane and can treat up to 250 gpm.

Refinements are continuously being made on recovery units in use in paper mills. Klebanoff and Bueltman (90) describe control systems for improving flotation saveall performance. These controls are concerned with maintaining constant pressure and flow and an automatic weir to insure uniform operation of sludge scraper blades. Quirk (141) found that 70 per cent of the total BOD of boardmill effluents was in a dissolved state. Sedimentation periods of 60 to 90 min result in removals of 70 and 11 per cent, respectively, of the suspended solids and BOD of these effluents. Chemical treatment employing iron and aluminum salts in dosages of about 100 mg/l and coagulation aids were required to obtain a maximum BOD removal of 30 per cent.

Klinger (91) reviews methods for handling the discharge of boardmill effluents for their reuse. Examples of both primary and secondary treatment plants are given. The biological treatment unit type is designed to treat 14,600 lb BOD daily and test runs have shown that removals of 89 to 96 per cent can be achieved. Sludge thickening and digester facilities have been provided for disposal of excess activated sludge.

The problem of the dewatering and disposal of solids resulting from the clarification of paper and pulp mill effluents remains one of the more difficult problems facing the industry. Nadelman and Newton (118) report on the chemical and physical characteristics of deinking sludge as related to the possible reuse of these solids in the deinking process or in other products. The utilization of modified sludge as filler for paper and rubber goods and as building material appears possible.

It would appear that disposal rather than reuse of paper mill sludges will be the treatment of these materials in the foreseeable future. A review of the nature of the problem, research and development activities, and current methods of sludge handling, are reviewed by Blosser (27). Data are given on sludge thickening, centrifuging, and filtration, and while there appears to be no universally applicable solution to the disposal problem, maximum concentration of solids prior to dewatering is desirable in all cases. Field studies on the use of a conveyor type centrifuge in dewatering board mill waste solids showed that cake solids greater than 28 per cent could be obtained at moderate flow rates (121). Preliminary estimates for dewatering low solids content sludge indicate a cost of $6.25 per ton of dry solids for the process, making it competitive with vacuum filtration. Tests (119) on a series of paper mill sludges have indicated that these sludges could be handled in conventional sludge-burning equipment. The volume of ash produced from burning

has ranged from 48 to 81 per cent less than the volume of the initial sludge.

Various types of biological oxidation processes are being used to reduce the BOD of pulp and paper mill wastes. A general review of oxidation lagoons is made by Blosser (28). More oxygen transfer by surface reaeration per unit of volume can be obtained by storing at shallow depths, preferably less than 3 ft. The addition of nitrogen and phosphorus accelerates the rate of BOD removal as does the introduction of free oxygen by natural or mechanical means. O'Conner and Eckenfelder (127) report that BOD removals up to 80 per cent have been obtained on paper mill waste in aerated lagoons and conclude that this process affords an economical method of waste treatment where land is available.

The use of plastic trickling filter media has been studied by Egan and Sandlin (54). Loadings to 750 lb BOD/day/cu ft of hot well condensate plus miscellaneous wastewater from an integrated kraft mill were applied without impairing efficiency. Removals of approximately 50 per cent were obtained. At temperatures in the range of 45 to 60°C, a biota was developed which was able to reduce effectively the BOD of the waste. Waldmeyer (168) describes a small diffused air activated sludge plant in England. The effluent has a very low BOD (below 10 mg/l) and an average suspended solids concentration (below 30 mg/l).

Finally, a process is under development at the University of California (6) which may result in the elimination of waste effluents from chemical pulping. In the process, wood chips, sawdust, and other logging residues are first treated with HNO_3 and NH_4OH. The wastewater is neutralized by mixing and the solution distilled to remove excess NH_4OH. The resulting neutral solution contains ammonium salts of organic acids and some residual HNO_3 and can be used with or without concentration as a fertilizer.

Tannery Wastes

An investigation of excessive incrustations in domestic sewers by Bolde and Rosenthal (29) indicated that this condition was due to untreated tannery wastes discharged to the sewers. It was found that the tannery waste with its high caustic lime content caused a calcium incrustation along the wet perimeter of the sewer below the tannery. This scale built up to almost an inch thick. Laboratory study indicated that mixing the tan waste with the beamhouse waste and sewage resulted in precipitation of calcium plus iron and chromium very similar to the composition of the scale found in the sewers. Laboratory experiments also indicated that the tannery sewage mixture formed an appreciable amount of incrustation.

It was found that treatment of the tannery waste with flue gas, reducing the pH to 9.0 or lower, would remove most of the calcium.

The best results for the removal of calcium and the other metals can be expected when the beamhouse and tan waste are mixed and settled prior to the carbonation. Other experiments also indicated that practically no incrustation occurred if the tannery waste was pretreated by carbonation, followed by settling, prior to mixing with the sewage.

Jansky *et al.* (84) carried out a study on the effects of tannery waste in Czechoslovakia on the Drevnice River. Their study included chemical, biological, and bacteriological methods. After a 30- to 175-fold dilution by the river water, 80 per cent of the sludge was removed by settling. No increase in BOD or alkalinity was noted after the tannery waste was in the river, only the brown colored tannins remained. At dilutions of 50- to 100-fold no decrease was noted in the self-purification capacity of the river. The self-purification capacity of the river was estimated by determining the deoxygenation and reaeration constants K_1 and

K_2. The authors advocate the use of K_1 and K_2 to determine the intensity of the self-purification capacity of a river in each case where a treatment plant is contemplated to avoid building unnecessary plants.

Studies were made by Orlita and Svec (129) on dilutions at which these wastes were lethal, toxic, and harmless to three river organisms. In general, all the liquors except the lime wastes were harmless at small dilutions. Lime liquors required dilutions of up to 200 to 1. The relative pure tannin in wastewater from vegetable and chrome tannage is more toxic to bacteria than the waste tan liquors containing 0.5- to 1.0-per cent tannin. The vegetable tan liquors and wash waters required dilutions as high as 1 to 800 to render them harmless to test organisms. Waste chrome liquors were harmless at dilutions of 1 : 20–60. Toxicity of the effluent depended on the pH value, and also the syntans were more toxic than the natural tannins.

Textile and Wool Scouring Wastes

Brown (34) discusses the work he has carried out on the effect of temperature and ventilation on high-rate trickling filter operations treating mixed cotton bleachery waste and domestic sewage. During certain periods in the summer the air temperature and the waste temperature were so nearly the same that these filters received improper ventilation, thus causing extensive odor problems. The installation of forced ventilation on the two trickling filters cured this serious odor problem and also increased the efficiency of BOD removal through the plant by an average of 10 per cent.

Neas (122) states that the treatment of viscose waste is not difficult. He then details some methods used. The sanitary sewage from the plant was treated by Imhoff tank, trickling filter, and final settling. The sulfide wastes were treated on a trickling filter. The acid waste was equalized, then blended with the alkaline wastes followed by neutralization with slaked high-calcium lime. This neutralized mixture was clarified in a circular upflow unit. The clarified wastes were then mixed with the sanitary plant and sulfide filter effluent and then passed through polishing lagoons to the river. Sludge from the clarifier was filtered by vacuum filter and stored in lagoons. Since this plant has been in operation it has been found that the trickling filter used for sulfide wastes was not needed. These wastes contain polysulfides which form free sulfur when neutralized instead of hydrogen sulfide.

The major problem encountered was with the sludge. A change in pH in the neutralization process to remove zinc resulted in a sludge that filters poorly. This problem is still under study.

Some discussion was given to the equipment used in the plant with comments on design factors, materials, and material coatings for surface protection. Also some discussion was given on a method for feeding lime, and the problem and results encountered with the precipitation of gypsum when the acid concentration of the blended waste exceeded 1,500 mg/l.

Maluskov *et al.* (104) reported on an ion exchange method of absorbing zinc from viscose wastewater as the zircate ion. This was done with an anion exchange resin. Nosek and Krepelka (126) discussed full-scale clarification test on textile waste by means of $MgCl_2$ indicating that in a highly alkaline medium it was a very effective clarification agent.

Stopler *et al.* (154) described their dilution experiments on viscose wastes. At a dilution of 1 to 10 of the viscose wastewater, the water bacteria showed a delayed development of 24 hr. A dilution of up to 1 to 50 delayed the biochemical oxygen consumption. It was found that fish did not seem to be affected by dilutions of 1 to 10 and above.

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INDUSTRIAL WASTES—RADIOACTIVE

General

The review last year referred to the Monaco Conference on disposal of nuclear wastes held in November 1959, but since the proceedings had not appeared, none of the papers presented there were included. During the past year, the proceedings were published in two volumes by the International Atomic Energy Agency (35) (36) and are reviewed under the appropriate headings.

Literature searches covering fixation of fission products (17), waste processing and disposal (18), and shipping and storage of radioactive materials (19) have appeared.

This review is organized under the subject headings: mining and milling operations; fuel reprocessing; waste handling, treatment, and disposal; and legislation.

Mining and Milling Operations

The treatment of uranium mill wastes was discussed by Lewis (44), who indicated that each ton of uranium processed resulted in the production of 300 gal of liquid effluent. Radium present in the wastes could be reduced by coagulation with copperas and lime and the addition of barites. Respective removals were: (*a*) alkaline tailings: 71 and 97.5 per cent; (*b*) acid resin-in-pulp tailings: no data and 88 per cent; and (*c*) clarified resin-in-pulp acid tailings: 94.2 and 99.9 per cent. Laboratory-scale experiments by Goodfellow *et al.* (29) with cation and ion exchange resins showed that they were ineffective for the primary removal of uranium from factory effluents. Recovery of thorium from sulfate solutions by a strongly basic anion exchange resin procedure was reported by Arden *et al.* (9).

Fuel Reprocessing and Separation of Radionuclides

Because of the decomposition of nitrate salts in concentrated high-levels Purex and Redox wastes, Anderson (6) cautions against the self-concentration of Purex wastes until additional research work on this problem is completed. Physical properties and flow characteristics of neutralized Zirflex waste were investigated to assist in the selection of satisfactory transfer equipment and storage conditions (5).

A cesium alum process is described in which the alum crystallization is carried out in an alcohol medium, thus eliminating the need for heating and cooling the solution (46). A decontamination factor of 10^6 is claimed for a single co-crystallization, and the amount of alum used is reduced to $\frac{1}{6}$ of that previously required. In another process patented by Burgus (15), fission products are precipitated on nickel or ferric ferrocyanide. The cesium is dissolved with a solution of ammonia or mercuric nitrate. Ames (4) reported that clinoptilolite, a zeolite, satisfactorily removed cesium from a high-salt solution over a pH range of 1 to 12 and at flow rates of 20 to 200 gph/sq ft.

Shaking solutions of strontium-90 with finely divided solid barium sulfate served as a basis for removing the radionuclide (45). Column treatment was suggested for better separation of strontium-90 from aqueous solutions.

Waste Handling, Treatment, and Disposal

General

The technical and administrative aspects of radioactive waste management were discussed in terms of the present and the future by Wolman and Lieberman (79). The authors distinguished between radiation protection standards and operating or performance criteria that must be established in connection with effluent control operations. Radioactive waste practices at Argonne National Laboratory were reviewed by Rodger (65), at Harwell by Burns (16), at Chalk River by Mawson and Russell (48), and at a German plant by Hoffmann and Talsky (31). Kenny (39) and Rogers (66) discussed the waste disposal problem related to the handling, use, and management of radioisotopes. The public health problems associated with the nuclear industry were referred to by Dunster (21). He also described the waste disposal practices of the United Kingdom Atomic Energy Authority (22), and Dickson (20), the problems expected

with a nuclear power program in England. Piccot and Wooldridge (61) determined the volumes and levels of radioactivity expected in the operation of the Piqua, Ohio, reactor facility and investigated various methods and costs of storing or disposing of such wastes. Two Russian papers appeared. The first was concerned with the separation of radioactive materials by coprecipitation with calcium oxalate (14). The precipitate is treated to isolate cerium (by an oxidation process), strontium (by coprecipitation with $CaNO_3$), and yttrium and the rare earths (by solvent extraction with tributyl phosphate). Ruthenium is concentrated from the supernatant on a precipitate of nickel sulfide, and zirconium and niobium on a precipitate of iron hydroxide; the precipitates are dissolved in nitric acid and the radionuclides are extracted with tributyl phosphate. In the second paper, Berezina and Golikov (12) suggest that stable iodine be added to wastes containing radioactive iodine before release from hospitals. Experimental results reported by Adams *et al.* (1) on a waste solution, 8 N in HNO_3 with 400 mg/l of iron and a molecular ratio of HNO_3 to HCHO of 1.7 to 1, indicate a reduction in the final volume of 40 per cent after treatment.

The Animas River Survey results for 1958 and 1959 were reported by Tsivoglou *et al.* (76), and gave the extent of radioactive pollution in the wastewater discharged from a uranium mill at Durango, Colorado.

Suggestions have appeared in the literature of disposing of radioactive wastes in arid regions such as the Atacama Desert, Chile (23) and in polar ice (58) (59) (60).

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Tank Storage

Jury (38) calculated steady state heat losses for the six cylindrical liq-

uid radioactive waste storage tanks at Oak Ridge National Laboratory and reported losses per tank ranging from 4,000 to 44,000 Btu/hr depending on tank location and moisture content of the soil. Simplified equations for calculating maximum temperature rise in stored solid radioactive wastes were presented by Godbee and Roberts (27). These authors stress the need for determining the thermal conductivity values of the solid wastes.

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Chemical Treatment

Coagulant aids for the lime soda treatment of low level radioactive wastes were studied at Oak Ridge National Laboratory (75) and Hagan Aids Nos. 50 and 18 showed some value under conditions investigating feed solution concentration, mode and point of addition, and water temperature. Krawczynski (41) investigated the effects of complex-forming compounds on chemical precipitation and reported that very slight traces of tartaric acid, citric acid, EDTA, and other chelating agents had a marked effect, but that commercial detergents exhibited no effect. Russian practice in treating low level wastes was described by Spitzyn (74). Zirconium-95, niobium-95, rare earths, some ruthenium-103, ruthenium-106, and a little strontium-89 and strontium-90 are coprecipitated with basic ferric sulfate and sodium hydroxide. The strontium, ruthenium, and cesium-137 remaining in solution are removed almost completely on passage through cation and anion exchange columns. Krieger *et al.* (42) reported that by a process combining co-crystallization, coprecipitation, and liquid-liquid extraction, a method was developed for the removal of long-lived hazardous fission products from a simulated acid aluminum nitrate fuel processing waste. Involved is cesium co-crystallization with potassium alum, followed by strontium coprecipitation with barium sulfate and solvent extraction of the rare earths, ruthenium, and zirconium-niobium with tributyl phosphate for a removal of 99.9 per cent of the total radioactivity.

Ion Exchange and Electrodeionization

The physical and physiochemical properties of liquids, as they relate to ion exchange, were studied; equilibrium constants for strontium-90 and cesium-137 ions in the presence of Ca and Na were calculated; kinetics of ion fixation was discussed; and the migration of radioactive ions in soils was considered briefly (10). Smit *et al.* (73) propose ammonium molybdophosphate (AMP) as an ion exchange material for removal of cations from acid and neutral solutions of fission products.

Glueckauf (26) discusses the theory and optimum operating conditions of a packed-cell electrodialysis unit for the final step in the treatment of dilute radioactive ions. Electrodeionization was investigated by Sammon and Watts (68) for the treatment of low level wastes. Their studies with Na salt solutions in the range of 10^{-2} to 10^{-3} N revealed the process can reduce this amount of salt by 1/2,000 and concentrate the effluent up to 100 times the influent. Deionization of solutions containing Ca^{+2}, Fe^{+2}, and PO_4^{-3} were investigated and the performance of the units was expressed in terms of a parameter which is a function of the solution concentration, flow rate, and desalting current. Japanese studies (51) showed that the transfer rate of either non-radioactive or radioactive ions through ion exchange membranes was nearly equal. In two-stage treatment the concentration of effluent rose to 100 times the initial feed. Power required

for electrodialysis was 1 kwhr/sq m when demineralizing from 2,000 to 20 mg/l, and the over-all power was only 10 kwhr/sq m. Current efficiency was over 70 per cent. Shimokawa and Nishio (71) describe an electrolytic deionization apparatus combining spherical ion exchangers and permselective ion exchange membranes. Equations were derived as a function of feed concentration, flow rate, electric voltage, current, current efficiency, equivalent conductivities of ion exchangers and solutions, volume fraction of particles, and cell geometry. They report that the electrolytic process incorporating resin particles and resin membranes is superior to the simple process using only permselective membranes.

Fixation

High activity fission product wastes from the reprocessing of spent stainless-steel fuel elements were fixed by fusing with lime and sand to a glassy state (28). Up to 70 per cent by weight of the calcined waste oxides were immobilized. At high temperatures cesium-137 would be lost from the fusion. Costs of waste processing by glass formation and storage would approximate 0.1 mills per kwhr of electrical energy produced. In Canadian experiments described by Bancroft (11) and Watson *et al.* (78), glass containing up to 50 c of fission products per kilogram has been produced with nepheline syenite. Ruthenium and cesium are volatilized in varying degrees during heating, and are removed by a method which permits subsequent incorporation into glass. Because of losses of radioactivity by leaching, the suggestion is made that the highly radioactive glass be buried in the ground or stored in artificial vaults (78).

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Calcination

Several laboratories have continued studies on calcination of high level radioactive wastes and the problems associated with such operations. Slansky and Warzel (72) describe laboratory and pilot-plant investigations on the dynamics of fluidized bed operation, the removal of volatile fission products and solid particles from gases, the development of equipment and operating techniques, and the long-term disposal aspects of all radioactive wastes. Removal of volatile ruthenium by silica was reported to improve with successive wetting and drying cycles. Similar studies by Anderson and Rhodes (7) show most effective adsorption on silica gel at a temperature just above the dew point of the ruthenium off gas. Heat transfer mechanisms associated with the operation of spray calciners were studied at Hanford (2) (53). Progress is reported in the processing of low acid waste and TBP-25 waste (54), Idaho Chemical Processing Plant waste (55), and Purex-type wastes (55) (56). Leaching studies (25) showed that very little uranium was leached by rain from alumina following treatment with caustic soda. This converted the uranium into an insoluble diuranate which was adsorbed by the alumina.

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Ground Disposal

Harpaz (30) suggests that alluvial soils be used for low and medium radioactive waste solutions because their

granular constituents are a good hydraulic medium suited for mathematical treatment and the salts and clays present have a high absorption and exchange capacity. Assuming that the motion of ions in ground water through soils may be described as a reversible process of exchange, Newton (50) calculates the distribution of activity through the soil by a statistical method. The mean delay time in a uniform column is determined by the equilibrium distribution ratio D and the shape of the front is fixed by D and a parameter N which represents the average number of transfers from the liquid to the solid state. Rowe (67) presents data on flow rate distribution calculated from a two-dimensional percolation model. Percolation test results are reported by Amavis and Vaccarezza (3) for H^3 and Sr^{90} in Saclay soil and are compared with mathematical formulations introduced by Hiester and Vermeulen and Kaufman. Rhodes (62) shows that more than 90 per cent of the cesium and less than 10 per cent of the strontium is absorbed by Hanford soils. Strontium removals could be enhanced markedly (>90 per cent) by increasing the pH to approximately 8 to 10. The movement of wastes through soil from Chalk River wastes was reported by Parsons (52).

Temperature buildup from ground disposal of highly active wastes was calculated by Kotewale and Ganguly (40) and Perona and Whatley (57).

Watkins *et al.* (77) review general considerations pertinent to ground disposal of wastes and point out the advantages and disadvantages of waste disposal injection compared with other methods of disposal.

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Salt Disposal

The use of mined-out salt beds and salt domes is being considered actively by several investigators. Rich (63) reviews the various factors to be evaluated in selecting this method and the economies thereof. He concludes that the technique is satisfactory if an economical method of concentrating and fixing the waste into a non-leachable form is developed. The many complex structural factors including elastic stress, thermal stress, and stress redistribution due to plastic zone formation, were investigated by Serata and Gloyna (70) along with problems of temperature distribution, heat emission from the wastes, reduction in cavity volume, strength of salt, etc. The chemical reaction between nitric acid and sodium chloride, which produces chlorine and nitrosyl chloride, was studied by Kubota and Tamura (43) in its application to the disposal of Purex wastes in salt. These studies are reaching fruition in a pilot-plant evaluation at Hutchinson, Kansas (8).

Sea Disposal

The sources and nature of radioactive wastes from U. S. nuclear powered ships and methods of disposal are described by Ilitis and Miles (34) and Rickover (64). Activity levels associated with spent resins from nuclear ship reactors are reported by Schultz (69), and characteristics relating to the disposition of these resins in sea water are given. Bonniaud and Cohen (13) state that concentration is the simplest method of preparing waste sludges into slowly leachable materials for ocean disposal. The addition of sodium silicate to Portland cement without the use of sand resulted in the best composition. Holcomb (32) reports that

a mixture of 2 parts cement, 1 part resin, and 1 part water was optimum for fixing nuclear reactor system demineralizer resin. He indicates that only 0.44 per cent of the gross gamma activity leached after 2,540 hr of contact with simulated sea water.

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Legislation

Legal and administrative problems associated with the use of the seas for waste disposal were reviewed by Hydeman and Berman (33) and Manner (47). The kind of control required to protect the public health against hazards of radioactive waste disposal is considered first, followed by a general analysis of the legal problems posed by waste disposal (33). Emphasis was placed on the authority of coastal states to impose unilateral control on the disposal of wastes by other countries if their interests are affected adversely. Consideration is also given to how questions of control have been handled in the past and the various means that might be utilized for international control. Manner (47) brought up the problem of the enclosed sea and stated that provisions relating to the Conventions of the Law of the Sea did not adequately cover this case.

The International Commission on Radiological Protection released the report of Committee II on Internal Dose (37), which is identical in numerical values to Handbook 69 (49) released by the National Committee on Radiation Protection. Of much interest to control agencies is the first report of the Federal Radiation Council (24) entitled "Background Material for the Development of Radiation Protection Standards."

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PUBLIC RELATIONS ASPECTS OF PROMOTING A BOND ISSUE

Ted Sperling

Any discussion of the need for bond issues first should be examined from the perspective of how to pass a bond issue. As a result, this will be concerned mainly with highlighting trends which are making it increasingly difficult to pass bond issues for the services this group provides, because only by recognizing the factors responsible for these trends is it possible to design effective public information programs which may lead to their successful passage.

First, examine the specific problem as professionals concerned with sewerage and water facilities, or to be more exact, the lack of such facilities. Recently, the Metropolitan Sewer District of St. Louis and several other major water and sewer utilities were the basis for a published article (1) describing a comprehensive treatment of the fantastic problem facing the entire nation in obtaining desperately needed new facilities in order to eliminate pollution and secure an adequate supply of water for expanding family and industrial needs.

The article said that the lack of sewerage and water facilities is the most neglected of all the public works problems arising out of postwar prosperity, mobility, and population growth. It also pointed out that ". . . The U. S. Public Health Service in a community by community survey found that nearly half of the 100 million Americans who have community sewers do not have adequate sewage treatment facilities.

". . . The United States investment in municipal sewerage systems is at least $6.9 billion short of what it should be, and in waterworks is short by $4.6 billion of the needs. In the next seventeen years, to correct today's deficiencies and to provide for the expected surge in population and for depreciation of existing facilities, . . . the nation should spend at least $44 billion on waterworks, sewers, and sewage treatment plants. This would mean spending $2.6 billion a year—which is about twice the average rate of outlays for this purpose since 1946. Of the two problems—water and sewage—the latter is by far the more critical.

"By 1975 at least 134 million people will be in areas with public sewerage, compared to 100 million today. To provide them with adequate sewage disposal, $24 billion should be spent.

"Last year, of the thousands of communities with inadequate water and sewerage facilities only about 600 were stirred up enough to put bond issues up before the voters. . . . Yet the citizens of nearly one-quarter of these 600 municipalities . . . turned down the bond issues at the polls."

The master understatement of the year was, "We've got a tremendous job to do."

Everyone surely has a pretty good idea of how his particular state or individual community fits into the picture just described. And just as surely as these needs are recognized, it is also recognized that only one basic com-

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modity can satisfy that need: Money; lots of money; and most of it general obligation and some revenue bond issue money.

This is elementary reasoning. Why belabor it? The point is made. But unfortunately the point was not made —yet. Because that same bond issue money needed so desperately for sewers and water also is needed and is being sought—just as desperately and usually more successfully—by the schools and municipal agencies who can only expand their services by securing tax dollars through bond issues. In short, this field today is in a competitive scramble for the tax dollar that is unparalleled in American history. And this competition—fierce, demanding, loud (and in the case of the public schools, bold)—comes at a time when the American citizen is plagued with a combination of inflation and higher taxes of every sort—a combination that shrinks the ability of the dollar he earns to buy everything he needs and wants.

Meanwhile, development continues without proper treatment facilities, without trunk and interceptor sewers, without adequate provision for ample supplies of good water. Each year of delay amplifies the problem and the cost of remedying that problem. And Mr. Taxpayer becomes more and more selective as to where, if indeed anywhere, he will permit his tax dollars to be invested for local bond issue proposals.

It's a discouraging picture. Yet, it is a true picture—almost a mirror of a situation each knows about close to home.

When management is ready for a project that requires bond issue financing, it generally tries to sell the bond issue to the voters on the merits of its case, usually through the medium of a select, blue ribbon citizens committee; and generally, with the support of the local press.

But as many a defeated candidate for office will testify, it takes much more than newspaper support to win a campaign. The same holds for a bond issue campaign in this field. Considering the background of fierce competition for the tax dollar and the fact that, in Missouri at least, a two-thirds favorable vote is required to pass a general obligation bond issue and four-sevenths for revenue bond proposals, it takes a concentrated, well-financed, professionally-directed campaign to successfully promote a bond issue in the face of today's adverse conditions.

This is true of the small community as well as the large. The small community has one advantage in that it is composed of people who have one basic geographical and economic interest. In addition, since lagoons may be presented as a low-cost alternative to conventional treatment plants in smaller cities, an attractive factor is added to such a bond issue campaign. Larger communities, on the other hand, have so many diverse interests it is difficult to select one thread with which to weave together all those interests into one affirmative movement for a bond issue.

Typical Program

Regardless of the size of the community, one fact remains basic: It does take a skilled, well-thought-out, and hard-hitting campaign to pass a bond issue election for sewers or treatment. Unless a community is willing to accept this fact, it cannot expect to win.

The type of program described is ambitious; yet, it is only a skeleton. Now the specific features of a typical campaign are outlined to illustrate what is really involved.

Committee Organization

A tightly-knit group of people functioning as an organizing and steering committee generally will be able to set policy, raise money, and steer the progress of the campaign much more

skillfully and effectively than a large loose-knit group. As a result, the following points should be carefully considered:

1. Start with a small group.
2. Consider this group as the nucleus of a future larger organization.
3. Let the small group be responsible for the points enumerated, and especially for raising the initial money.

In the case of most public agencies, money to run a bond issue campaign must be secured from private sources, inasmuch as the public agency is prohibited by law from contributing money for this purpose. The financing required for a campaign may be as small as several hundred dollars and as large as $15,000 to $20,000, depending on the community, the nature of the problem to be overcome, and other similar pertinent factors. In any event, the committee must have a clear-cut idea of how much money will be needed before the campaign starts.

Initial Support

The following points should be carefully considered in the planning of the over-all campaign, especially in the background planning:

1. In lining up initial support the committee should always be sure to ask for money. In most cases, the committee will not get this money. However, its request and subsequent refusal will plant guilt feelings within those organizations and individuals who refused to contribute. This will be a big help later when the committee must recruit speakers and workers who are willing to give their time, if not their cash.
2. Although all organizations of a civic nature should be contacted by mail and in person and familiarized with the bond issue, and a request made for money, committee members should concentrate their efforts on those individuals and organizations they know, from previous experience and on the basis of community relations, will be most likely to offer financial assistance and actual organizational support.
3. After its initial planning has been developed, the steering committee should enlarge its numbers to include a wider range of key people who can be assigned responsible committee posts and, who in turn, may secure other key people to widen the scope of the bond issue campaign as the need arises.

Over-all Planning

Such planning should generally be done by the steering committee before it enlarges its numbers in order that it might have a complete blueprint of what needs to be done. This helps immeasurably in gaining the support of other key people who are willing generally to accept specific assignments and who will react favorably to a specific blueprint, rather than generalities about what may be needed. The following points should be considered very carefully:

1. Be willing to pay a fair price for professional public relations help. You will save time and get your story across better. Give that professional help a strong voice in initial policy decisions; it is paid for what it is supposed to know about shaping public opinion.
2. Have all elements of the program and strategy complete and agreed on before any publicity is released and—repeating an earlier injunction—before the committee is enlarged.
3. Decide in advance what ideas can be sold to the community. Remember, in this phase of planning, that you must overcome fear, doubt, animosity to increased taxes, and lack of tangible benefits.
4. Here are some of the basic factors which a committee should consider as the nucleus around which one over-all, affirmative central theme for the campaign may be constructed:

(*a*) Individual health protection. Present this point in such a way as to make people compare the cost of the improvement with what they would have to pay for more health insurance, doctor and hospital bills, etc., if an epidemic disease were to strike their families.

(*b*) Community benefit. One of the most effective methods of focusing attention on this point is the appeal to help spread the tax base, thereby lowering taxes generally. This obviously is done by making trunk sewer, treatment, and water facilities available in ample quantity to attract the investment capital, which in turn will achieve a balance of industry, commerce, and residential development. Constantly hammer the point that it is the taxes for the support of public schools which take the biggest bite out of the taxpayers' dollar. Point out that industry and commercial development can only come into a community where adequate facilities are available; business and industry contribute very few pupils to a school system, but they contribute enormously to the entire tax structure through the virtue of their tax assessment. This is a factor which is gradually beginning to be recognized and accepted in most communities, and it needs to be emphasized again and again.

(*c*) Outright fear of disease and the possibility of epidemics. This is a feature which has been very poorly handled in the past due to the rigid attitude of public health authorities. It is not suggested, of course, that reasonable standards of scientific inquiry and analysis be suddenly dumped for the expedient of frightening people. What is suggested is a more reasonable and forthright attitude on the part of public health officials on the local scene to warn of the possibilities of epidemic disease spread through untreated sewage.

5. An alternative to the bond issue for an example of what will have to be done if the bond issue is turned down. Here, it is necessary to be extremely cautious. People do not like to go to the polls with the feeling that a club is being held over their heads. On the other hand, a firm analysis and understanding of an unpleasant alternative will do much to help sell the affirmative appeal of the bond issue provisions.

6. Advantages of the particular type of bond issue. Specifically, if it is a general obligation bond issue, it should be pointed out that this type of financing insures that everybody who eventually moves into the area over the 20-yr period will pay his fair share of the improvement, and that the tax rate must go down for the individual taxpayer as the assessed valuation for the entire area goes up. In the case of a revenue bond issue, there should be no hesitancy whatsoever in affirmatively promoting the point that this type of financing takes nothing from the taxpayer in the form of a direct tax, but is paid for equitably by all people who share the service through the medium of the service charge. It goes without saying, of course, that the revenue bond issues generally are far easier to pass than general obligation bond issues, the obvious reason being that direct taxes are not required.

Timing of Publicity

Start no sooner than 60 to 90 days before the election. Be extremely careful in selecting a date, and consider the following points:

1. The election should be held during the season when the problem is the worst. For example, trunk sewers or treatment obviously have their greatest voter appeal in hot weather.

2. Peg the election date during a period when there is assurance of adequate citizen help. In most communities a trend can be discerned for most vacations and other activities, regardless of season, which engage the spare time of most willing citizens.

3. Beware of unseen obstacles. For example, avoid an election date on or immediately near the date on which local tax bills are issued for that year, or at the time of the month when charge accounts are billed to customers.

4. Concentrate the heaviest effort of the campaign in the last 30 days before the election, mounting to a crescendo of activity during the last two weeks.

Liaison

Make sure that key members of the steering committee are available at all times to consult with the public relations people who actually will be running the campaign at this point. Liaison of this sort will avoid time-consuming delays on key policy decisions which the public relations people do not have the authority to make, but which inevitably crop up during crucial periods in a campaign, usually when least expected. Unless these key people are available and are ready to make a decision quickly, valuable time and initiative may be lost.

The Campaign

The campaign depends on three key factors: money, media, and people.

Money

The over-all need for money has already been discussed. Briefly, it will be needed for telephone and office, postage, printing, movies, photos, engravings and mats, and print advertising. It will not be needed for feature stories, news coverage, TV and radio spots, etc.

Media

All of the following media and illustrations of use should be considered:

1. Newspapers These include: (*a*) news stories, (*b*) photos, (*c*) feature articles, (*d*) letters to editor column, and (*e*) editorials. All of these will be handled adequately by a professional public relations agency, and there should be no attempt made on the part of the committee to control the release or strategy in this regard. The campaign always should be started by the steering committee in a meeting with the local press, radio, and TV. This should be a joint meeting and the top executive talent in the committee should handle the details. Explain all facets of the bond issue; dodge nothing. Tell the press representatives exactly what is your program, your problem, and your solution. Be frank. Recognize that in order to gain full support for the bond issue, your committee must convince these people.

2. Television.

(*a*) Consider producing 20-, 30-, and 60-sec spots which public service minded companies such as banks and utilities will sponsor, without charge to the committee, on their own television shows and spot schedules. This is commonly done, for example, in United Fund drives.

(*b*) If a film is produced, it should be so timed that it may tie into 15- and 30-min public affairs programs. These should be handled on a live panel basis. Generally, the moderator will introduce the panel members, present the problem, and then show the movie. After the movie, a panel discussion is then in order. Television should be hit hard and often, with this precautionary measure first considered: *Be sure the appeal on television is tangible, simple, and direct.*

3. Radio. All phases of radio are completely covered in the discussion of TV, and treatment of this media should be exactly the same as for television.

4. Movies. A word of precaution is necessary here. Movies, unfortunately, too often are considered as "cure-alls" by bond issue sponsors. By all means plan a movie if it is possible to finance one. Remember, however, that just as a few advertisements can do more than bring people into the store, so movies should not be expected to convert

votes, but basically to acquaint large numbers of people with the basic problems and the proposed solutions. A professionally produced movie of 12 to 15 min will average a minimum of $3,000 to $5,000 if professionally and skillfully done. However, committees should not overlook the possibility of producing movies with amateurs, provided that their aims are simple enough to be fulfilled by amateur camera talent.

Prepare the movie well in advance of the bond issue and begin showing it no later than 30 days before the bond issue vote.

Be sure to have ample copies available for cutting up and editing by TV stations for use in news shows and special event programs.

Educate speakers for the bond issue on the use of the movie projector, and rent sufficient projectors for simultaneous showing to local PTA groups, civic organizations, etc.

It is important to emphasize the need for the individual water pollution boards and state departments of health to provide professionally produced films, detailing the general problems which all communities face, and which the individual cities may obtain from the state for a per-copy price or free of charge. This is an educational area of pollution elimination and expansion of water resources which still lags far behind the need.

5. 35 mm slides. This is one of the finest low-cost methods of effectively presenting the problem and getting it across to a mass audience. Slides may be made on location and by amateur photographers at very little cost. Consider these following points:

(*a*) Shoot many copies of the same scene in order to provide sufficient copies for the speakers.

(*b*) Develop a specific talk built around a series of 35 mm slides. Rent or buy 35 mm slide projectors which speakers may carry with them. Inexpensive and simple sleeve inserts are available for these slides. The insert is then simply slipped into the projector and the speaker does not have to worry about keeping the slides in order. The whole kit is light, easy to use, and effective.

(*c*) Be sure to render on 35 mm slides all maps, diagrams, and other material which can be projected in large relief for mass audiences to see clearly. Small copies of maps and diagrams are practically useless before audiences.

(*d*) Keep in mind that the speaker, as well as the viewer, can benefit from use of the slides. Many speakers will want these slides as their own visual aids while they are learning the semi-technical portions of the bond issue which they must explain to voters.

6. Bus tours and in-plant visits. It is axiomatic in pollution abatement that "yes" votes are gained when people actually see and smell the problem. Nothing is as effective as visits to the site. Bus tours are particularly effective and are easily handled. Generally the group can meet at a shopping center or some other easy-to-find point. The group leader should spend 10 to 15 min explaining what will be shown, and in every case, should distribute printed material which the tourists can refer to as they move from point to point on the tour.

7. Direct mail. Here is one of the most effective tools in promoting a bond issue when used properly. Since the increase in postage rates for all classifications of mail, rates for hand-delivered media may prove lower than mail. In either event, here are some general points to consider:

(*a*) Create a newsletter which is distributed to all voters. It should be sent out weekly or biweekly and should contain in easy-to-read, attractive fashion the basic considerations the committee wants voters to consider. It should have a distinctive makeup and may be produced for very little money.

(*b*) Always be specific and to the point in direct mail. Do not try to sell everything in one presentation. To be effective, direct mail must be repetitive.

(*c*) Consider personally-signed postcards which can be printed in advance and signed by proponents of the bond issue, and mailed by them to their own lists of friends.

(*d*) Always have a final mailing which will reach the voter the day before the election. Always include a sample ballot which has been premarked in the "yes" column, and include a brief and strong résumé of the points for the proposition.

8. Testimonials. The committee should work hard to obtain strong endorsements from doctors and community leaders as well as people who are not so well known throughout the community, but as leaders in their own neighborhood. It is always a mistake to overlook the local "big fish" in the small pond. In many instances, large segments of the community will resent the fact that people they know are not represented on a blue ribbon committee.

People

In the final analysis, people who work in the campaign are by far the most important factor in the success or failure of a bond issue. It is a rare instance where use of printed media alone can accomplish the job. By the same token, a well-organized, devoted group of interested citizens can do their own work exclusively, and without the aid of the points mentioned above, pass a bond issue. The committee should develop block organizations with captains and block workers situated on every block of every neighborhood. Speakers who are capable of addressing public meetings of every kind should be developed promptly. Important points are as follows:

1. Be sure that the speakers are educated together in a well-thought-out and illustrated program.

2. Do not expect laymen to be capable of explaining technicalities which only engineers and other technical people are familiar with. It is far better to have a technician accompany a speaker and answer questions referred to him by that speaker, than to have the willing public speaker attempt to answer something he has no background on.

3. Keep in regular contact with all the people in the speakers' bureau. It is necessary for them to be enthused and constantly convinced if they are to do an effective selling job on the voters.

4. Visual aids are tremendously important and should be provided for. In this instance, refer to the section on 35 mm slides and movies.

5. Utilize the people who are supporting the bond issue for an all-out effort during the final day. Actually organize a "blitz squad" and let it work for you in literally pulling out votes on the day of the election. Here is how this should be done:

(*a*) A map should be prepared in advance showing all precincts and wards in the area. Post it in a conspicuous place at headquarters. Have responsible people analyze and record the number of the highest votes during a presidential election for the same area. Then prepare a cross reference of these results with each precinct or ward on the map.

(*b*) Every two hours during election day have couriers visit each polling place to obtain the total number of votes cast. They will not, of course, be able to find out the "yes" or "no" count, simply the total. The couriers then relay this information in person to headquarters and results are posted on the map or the board under the appropriate time of the day. Keeping in mind that the vote between 4:00 and 7:00 PM generally will be at least twice

as heavy as the vote from 6:00 AM to 4:00 PM, analyze the returns according to precinct.

6. Have the blitz squads leave headquarters and drive into areas where results up to that hour indicate the vote is lighter than it should be. Have these couriers work on a block-to-block basis within the precinct and ward and literally knock on doors to offer people rides to the polls. In the process, they almost always will convert homeowners to a "yes" vote.

Post-Campaign Activity

Have the public relations people prepare a victory and defeat statement in advance, both premised on policy which the committee has developed prior to the election and which may be implemented immediately thereafter. If victorious, observe all the amenities and be certain that everybody gets plenty of credit for his effort.

If defeated, have the committee meet immediately and again the following day to discuss the policies which it will recommend in view of the defeat. No sensible organization of intelligent citizens ever should enter a bond issue campaign without recognizing squarely the overwhelming possibility of a defeat. Such recognition surely will not adversely condition their will or determination to win, but will instead, sober them to the overriding necessity of providing for alternative plans in case of a defeat. Just as no modern army would enter a battle campaign without alternative plans of action should it meet temporary set-backs, so no bond issue campaign should ever overlook the necessity to plan in advance for the possibility of a defeat.

Pollution abatement, expansion of water facilities, building almost any improvement by a bond issue means may often be a discouraging process. This is the nature of the problem and the restricted means which public agencies have available for progress in their respective fields. In closing, this last point is emphasized by quoting from an article prepared for the editorial page of a metropolitan daily, and which appeared the day before the $4.1-million Gravois Creek bond issue election which the Metropolitan Sewer District lost by only 190 votes out of 11,000 cast. Whether the issue faced is water, sewage treatment, or trunk sewers, the message will apply because it actually is hopeful and the results of the election were heartbreaking. The combination sums up the total picture for many agencies:

> The condition of the Gravois Creek (and here you may just as well add the name of the outstanding pollution or water problem in your own community) is an affront to human dignity. A foul, stinking, disease-infested open sewer has no place in a modern American community in the middle of the twentieth century. To endure a condition of this sort and the threat—the very real threat—it poses to us and our children is unthinkable. The proposition to eliminate this condition is the best, most economical and only long-term solution. It deserves the unqualified support of every man and woman in the watershed.

Reference

1. Thompson, E. T., "The Worst Public Works Problem." *Fortune* (Dec. 1958).

HEAR WITH THE LAST WORD IN TECHNICAL KNOW–HOW AND SEE THE LATEST IN EQUIPMENT AND SUPPLIES—
SEE PAGE 668

WHERE INDUSTRY STANDS IN WATER POLLUTION CONTROL

A. J. Steffen

Any discussion of where industry stands in water pollution control can best be opened by evaluating the past, determining industry's position in the present, and pointing up trends that are shaping the future. This is an ambitious task, especially in a field so lacking in accurate basic data.

In dealing with this subject, the author speaks about industry, but not for it. It would be presumptuous for anyone to speak for all of industry on this broad and somewhat controversial question. However, sanitary engineers in industry, as well as many officials of state water pollution control agencies, have helped to develop this discussion by providing valuable background data.

Evaluation of Pollution

Hoak (1) presents a clear-cut definition of pollution: "Pollution is the discharge of material that unreasonably impairs the quality of water for maximum beneficial use in the over-all public interest." However, he hastens to add, "The difficulty with the simple definition of pollution just given lies in our inability to assign a quantitative meaning to unreasonable impairment of water quality."

The stream sanitation picture is made up of many individual mosaics—individual reaches of streams where municipal and industrial effluents are discharged. The determination that any effluents are polluting the stream depends on whether the stream can accept such effluents without impairing the quality of the water for maximum beneficial use in the public interest. Regulatory agencies must determine the quality limits for the effluents in question, based on the needs demonstrated by the various competing uses of the stream.

In 1938 Streeter (2) set down the principles of evaluation of stream quality in these words: "To solve this problem (of evaluating pollution) rationally, it is necessary to analyze it from the standpoint of the relative effects of various upstream population groups on conditions of pollution at the particular point of interest downstream." Note that it is necessary to deal with the effect of the effluent on the stream, not the effluent itself.

This principle seems relatively elementary, but it warrants reemphasis, inasmuch as some analysts have, in recent years, attempted to evaluate the national progress in pollution control by citing totals of BOD or population equivalent discharged. This approach does not measure pollution. It measures effluents rather than their effect on the stream, and it classifies as pollution increments the thousands of municipal and industrial effluents discharged in full compliance with all regulatory requirements.

In assigning a quantitative meaning to impairment of water quality in a specific reach of stream, the economic value of each use of the stream water is an important but often neglected in-

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gredient. In an evaluation of costs versus benefits in stream pollution control, the Food Research Institute (3) of Stanford University, under contract with the U. S. Public Health Service, concludes that the pollution control administrator should "study and reflect upon each individual case, in the light of such general guidance as the economist can offer, and such factual information as he himself can muster." Cleary (4) expressed this philosophy more directly a few years ago when, in discussing the substantial cost of waste control in industry, he stated, "I display the dollar sign simply as a reminder that pollution control is a costly proposition and that no one can benefit from unnecessary restriction of waste discharge. Thus I plead that we embrace the concept that the quality conditions to be maintained in a stream should be related to use requirements. On that basis we have the opportunity to develop a pollution control program that is practicable, reasonable and rational."

Basic Data

Basic data on the effects of industrial wastes on water pollution for any period—past, present, and future—are very limited. A survey made in 1950 by the Conservation Foundation and the National Association of Manufacturers, published under the title, "Water in Industry," presents a substantial amount of data for that year, but the survey was centered around industrial water supplies with relatively limited information on waste disposal.

Currently, a survey is under way known as the Industrial Water Use Questionnaire sponsored by the Conservation Foundation, the National Association of Manufacturers, the Chamber of Commerce of the United States, and the National Technical Task Committee on Industrial Wastes, to obtain information on industrial wastes and industrial water use. This survey has been launched concurrently with the 1960 Census of Manufacturers, and augments the data to be obtained in the latter. Associations represented in the Task Committee are cooperating by clearing the questionnaires through their offices to their membership. A report based on the results, to be published in 1961, is expected to yield meaningful data on industrial water use, conservation, and disposal, and with the information obtained in the 1950 survey will tell something about the past decade and indicate trends and needs for the future.

An Estimate of the Situation

The report on the Industrial Water Use Questionnaire will supply some of the answers a year from now. But how can current progress in pollution control be estimated?

A state director of pollution control suggested that industry's position could be explored by considering the number of cases corrected and the number of cases or treatment needs pending in any selected representative area. Because a case or problem (be it of municipal or industrial origin) is a problem because of its effect on a stream, it is an element in pollution control and can reflect stream improvement far better than effluent data. Using this approach, a questionnaire was developed (Figure 1), limited to three questions, for distribution to a few state stream pollution control administrators. Beginning with this modest approach, the evaluation finally covered the entire United States with the exception of Alaska, Arizona, Hawaii, Idaho, Montana, Nevada, New Mexico, and Wyoming. Of the 42 questionnaires sent out, 38 sets of data and questionnaires were returned with sufficient information to be tabulated (Table I).

It was emphasized to the respondents that where accurate data were not available, an estimate would be satis-

TABLE I.—The Pollution Control Situation as Estimated by State Agencies

State	Municipalities					Industries				
	1950		1960			1950		1960		
	Treatment		Treatment		Improvements Needed	Treatment		Treatment		Improvements Needed
	In Operation (1)	Needed (2)	In Operation (3)	Needed (4)	(5)	In Operation (6)	Needed (7)	In Operation (8)	Needed (9)	(10
Ala.	135	—	168	38	26	37	—	97	25	23
Ark.[a]	107	30	114	15	80	54	200	156	85	15
Calif.	340	134	578[b]	32[b]	—	—	—	1,420[b]	—	—
Colo.[a]	93	138	162	188	69	18	30	20	40	25
Conn.[a]	53	90	81	32	17	105	310	160	200	20
Del.[a]	35	51	45	51	5	5	350	342	383	18
Fla.[a]	36	134	456	50	40	30	30	150	200	100
Ill.[a]	299	125	383	199	59	92	150	230	75	50
Ind.[a]	85	150	144	125	27	250	50	321	16	54
Iowa	281	77	349	63	104	197[c]	403[c]	274[c]	225[c]	70[c]
Kans.[a]	182	88	330	5	35	5	75	41	30	15
Ky.[a]	73	61	105	34	32	85	125	176	40	35
La.	59	36	127	25	30	50%	100%	75%	100%	25%
Me.	11	40	21	35	45	—	—	12	25	20
Mass.[a]	62	83	117	33	20	49	200	79	181	22
Mich.[a]	154	128	262	25	71	199	139	392	15	56
Minn.[a]	220	110	309	73	115	110	50	298	45	57
Miss.[a]	7	175	64	87	100	0	40	4	36	40
Mo.	150	100	350	25	50	—[d]	—[d]	—[d]	—[d]	—[d]
Nebr.[a]	118	324	203	239	260	1	10	4	8	5
N. H.[a]	8	61	13	56	4	3	30	12	21	11
N. J.	410	50	468	15	50	70	—	74	10	5
N. Y.	298[e]	—	448	139	51	—	—	—	—	—
N. C.[a]	275	164	379	88	60	10	90	32	50	15
N. Dak.[a]	88	19	157	16	43	12	12	18	13	20
Okla.[a]	185	27[f]	269	12[f]	75	102	21	168	10	35
Ore.	97	96	181	62	33	27	88	358[c]	68	—
Pa.[a]	225	480	500	350	175	930	830	1,260	560	100
R. I.	15	2	19	0	3	3	418[c]	11	60	60
S. C.[a]	153	54	172	35	43	33	114	79	74	26
S. Dak.[a]	98	80	146	32	31	3	5	10	2	2
Tenn.[a]	67	46	108	30	37	70	112	186	70	95
Tex.	669	25	700	4	157	—	—	—	—	—
Utah	1	83	42	57[g]	—	3	100	10	100[g]	—
Va.[a]	142	300	405	100	20	170	150	225	100	10
Wash.[a]	83	177	230	62	37	175	525	1,018	109	109
W. Va.[a]	5	217	22	200	10	35	281	187	80	50
Wis.[a]	268	62	374	4	135	1,524	775	1,107	227	200
Total of 26 States	3,182	3,375	5,550	2,141	1,600	4,070	4,704	6,675	2,630	1,185

[a] Included in column totals.
[b] 1958 data; industrial data based on facilities provided since 1950.
[c] Includes industrial waste treated in municipal plants.
[d] No data available; Water Pollution Law effective October 1958.
[e] 1952 data.
[f] Sewered towns with no treatment.
[g] Includes "improvements needed."

YOUR ESTIMATE OF THE POLLUTION CONTROL SITUATION

State _____

1. What is your estimate of the number of municipalities and industries that

	(a) Were providing treatment in 1950?	(b) Are providing treatment now?
Municipalities	(Col. 1)	(Col. 3)
Industries	(Col. 6)	(Col. 8)

2. What is your estimate of the number of municipalities and industries that

	(a) Needed treatment in 1950?	(b) Need treatment now?
Municipalities	(Col. 2)	(Col. 4)
Industries	(Col. 7)	(Col. 9)

3. What is your estimate of the number of municipalities and industries currently in need of additions or improvements to existing facilities?

Municipalities	(Col. 5)
Industries	(Col. 10)

FIGURE 1.—Questionnaire used in survey.

factory, inasmuch as the estimate of the state administrator and his staff would be an authoritative evaluation. The total data from 26 states were summarized. All other replies omitted some data or deviated from the pattern of one or more of the questions. Respondents were encouraged to submit data in any form they wished if their records were not in such form as to facilitate answers to the questions as stated. This yielded an extensive bibliography, which aided materially in developing background information for this study.

A large portion of the tabulated data is based on estimates; the summarized statistics are presented only as guide lines. However, recognizing that an estimate would tend to be uniformly high or low, it is reasonable to expect percentages calculated from the data to be fairly representative of actual conditions.

An analysis of the totals for the 26 states indicates a 74.5 per cent increase in municipal treatment facilities and a 64 per cent increase in industrial waste treatment in the past decade. During the same period there was a decrease in needs of 36.5 per cent among municipalities and 44 per cent among industries. Recognizing that a portion of the municipal gain is also a gain in industrial waste control for those industries discharging into municipal sewers, it is evident that there has been substantial progress in the control of industrial wastes by treatment. Industries show less increase in waste treatment, but a greater decrease in needs. This reflects a trend toward consolidation of small plants and a movement of industries into cities, trends that reduce needs in industrial waste treatment without building separate industrial waste treatment plants.

The proportion of treatment facili-

ties as against the total requirements (that is, Col. 1 divided by (Col. 1 plus Col. 2)) presents some interesting figures. In 1950, 48.5 per cent of the municipalities and 46.5 per cent of the industries that needed treatment had treatment facilities. In 1960 these figures rose to 72.2 per cent of the municipalities and 71.7 per cent of the industries. Similar data for the ORSANCO (Ohio River Valley Water Sanitation Commission) drainage district show 48.4 per cent of the municipalities, and 87.9 per cent of the industries with waste control facilities in 1959. Just seven years earlier ORSANCO reported that only 26.5 per cent of the municipalities and 54.5 per cent of the industries had facilities in operation. Although many of the problems remaining after the first years of effort in ORSANCO and other postwar stream improvement programs are especially difficult to solve, the administrators of these programs can point to the record with justifiable pride.

Progress in Conservation

The record that no survey can show is the amount of water pollution control effected by waste conservation within industry. Waste conservation data are difficult to collect and are not readily summarized, but many examples can be cited.

There is the frequently repeated success story of the Fontana, Calif., steel plant, which uses 1,300 gal of water per ton of steel produced, whereas some of the older eastern mills use 65,000 gal/ton. The average fuel electric power plant uses 40 per cent less water per kilowatthour of electricity produced than in 1940, even without recirculation. The author has seen a meat packing plant reduce its waste flow by 20 per cent during a period of increasing kill. A week's work in a cheese plant and several thousand dollars of waste-saving equipment reduced the BOD of the total plant wastes by 50 per cent. A manufacturer (5) of penicillin reports a BOD reduction from 9.1 lb per pound of product without recovery to 1.4 lb with in-plant recovery. A distillery (5) reports more than 50 per cent reduction in BOD by in-plant waste saving over an 8-yr period.

Waste conservation takes many forms and is as complex as industry itself. It may involve a change in a process to eliminate a troublesome waste; it may mean developing new products to utilize a waste; it may mean incineration of wastes with heat recovered as a by-product; it may be recirculation of the water, or reuse after treatment. According to the 1954 U. S. Census of Manufacturers, industrial water requirements would have doubled if none had been recirculated or reused.

This part of industry's water pollution control program begins by instilling a consciousness for waste conservation in management and supervisory personnel at all levels. The sanitary engineer in industry has a selling job to do and his approach is often unique. He uses motion picture and slide presentations, chalk talks and group discussions, progress contests between plants, in-plant conservation committees, individual merit awards—one firm distributed pencils with waste conservation slogans on them. While selling waste conservation, the engineer must implement the effort by providing background information, waste surveys, and specific answers. He must furnish information on everything from self-closing valves for drinking fountains to entrainment separators on vacuum pans. Much has been done in wastes conservation, much is being done, and more needs to be done.

Industrial Wastes Research

Millions of dollars are being spent by industry in industrial wastes research, much of it on utilization and conservation of wastes. This cost rarely appears in the records as research in pollution control because it is usually classified as product research.

In waste treatment research, industry has certain inherent advantages over the municipal sewage field. For example, industrial waste treatment studies can be conducted on a semi-plant scale, and, if need be, on a full-scale trial-and-error basis—procedures generally not adaptable to municipal financing. Such studies have been stimulated in the postwar years by the work of industrial chemists and process engineers who have assumed responsibilities in the sanitary engineering field. They tackle each problem as a process problem, often breaking away from conventional treatment practices to develop entirely new processes.

Postwar efforts have led to significant break-throughs in industrial waste treatment—microbiological oxidation, disposal by irrigation, development of synthetic trickling filter media, the anaerobic contact process, air flotation, the use of ion exchange for removing dissolved ingredients, and disposal of sludge by wet oxidation, to name a few. Some of these processes, developed in the industrial field, have been adapted to the treatment of municipal sewage, notably microbiological oxidation and sludge disposal by wet combustion.

Trends Shaping the Future

Now, after looking at the progress of the past and positioning it in the present, what about the future?

The limited basic data on industrial waste control and the many variables that influence changes in the industrial complex do not permit a statistical evaluation of the future. However, in an unpublished survey among representatives of industry conducted in 1959, 23 respondents predicted an average of 100-per cent growth in industrial waste treatment by 1975, using 1958 as a base. Although this is obviously not a statistical projection, it is an estimate of the situation by men who know the field and so sheds light on the future.

Something can also be learned about the future by observing the trends that are shaping it. A few that should be examined are as follows:

1. Integration of industrial waste management with production.—The brightest star on the horizon is the increasing recognition among industrial leadership that disposing of the waste is part of the production job. No longer is the wastes management engineer an unwanted bystander when new plants and new processes are developed. Now he is a full partner in planning for process changes, in new products development, and in new plant design.

2. National Technical Task Committee on Industrial Wastes.—This group was organized in 1950 as an arm of the President's Water Pollution Control Advisory Board to assist the U. S. Public Health Service in industrial waste matters, and to facilitate an exchange of information in this field. It now consists of 65 members and alternates representing 34 industries. Membership is diversified to include a broad range of specialists to implement the committee's program. Currently, some of the activities are:

(*a*) Conducting the industrial waste and water use survey previously mentioned.

(*b*) Developing industrial waste guides to provide information to operators and managers of industrial plants, to consulting engineers, to personnel of regulatory agencies, and to superintendents of municipal treatment plants concerning the sources, characteristics, conservation procedures, and treatment of specialized industrial wastes. In this effort the leaders in industrial waste management are pooling their information in the interests of the entire industry. Guides have been completed for the milk, commercial laundering, cotton textile, meat, cane

sugar, by-product coke, and wood naval stores industries. A guide for the potato chip industry is in print, and guides for the general canning, citrus canning, fruit canning, synthetic textile, and textile printing industries are in process. These guides are published by the U. S. Department of Health, Education, and Welfare, and are distributed by the Public Health Service and the Superintendent of Documents. The Task Committee also publishes a *News Quarterly*, financed by its membership for free distribution to industry and to all regulatory and educational agencies concerned with this field.

(*c*) Industry education and public awareness program. A separate subcommittee is preparing educational brochures and a television packet, and is stimulating the development of training films.

(*d*) Research priority recommendations. A subcommittee prepares priority recommendations, outlining research projects of special interest to industry, based on an opinion poll conducted during the year.

(*e*) Manpower needs. The committee is stimulating interest and encouraging training of competent personnel for meeting needs in the industrial wastes field. In-service training programs are also developed by industries within NTTCIW and attendance at state and federal in-service training schools is encouraged.

(*f*) Preparation of an annual progress report by each industry group. In the ten years of the committee's life, these reports show consistent gains in the control of industrial wastes. They are published in the report of the annual meeting and are released to all interested news channels.

3. Changes in the Industrial Complex.—The hard facts of economies are in themselves operating to solve some industrial waste problems. Industrial plants are being outmoded at a faster rate. The average industrial plant was 27 yr old 15 yr ago. Today it is only 24 yr old. This accelerated obsolescence offers opportunities for the introduction of modern waste conservation measures and provision of waste treatment facilities in the new plants.

The consolidation of small plants in some industries (notably the dairy and canning industries) is also a trend that is bringing with it modern waste-saving features in new plants. In most cases, the consolidated plants are served by city sewers.

These changes, motivated by economies, have eliminated many potential and actual pollution problems, and will continue to do so in the years ahead.

4. Progress through constructive water pollution control programs.—This list would not be complete without a recognition of the progress in stream sanitation and industrial waste control that has been brought about by water pollution control administrators operating under reasonable and constructive regulations.

In most states stream pollution control is based on surveys of drainage basin areas. The Delaware Water Pollution Control Policy outlines in a few concise sentences a procedure that has been found workable in many states: "The waters of the state are studied and surveyed by drainage basin areas. These investigations show the current stream condition, the wastes being discharged, the effects of these wastes, and the best uses of the streams in the various areas. Based on the best uses in the various stretches of the streams, the Commission agrees concerning the degree of treatment that is needed for

each waste being discharged." The requirements are subject to review whenever warranted by changes in water quality or uses.

Industrial organizations have been actively supporting realistic practicable stream improvement programs based on accurate appraisals of stream use. In California, for example, R. T. Antrim, appearing in behalf of the California Conference of Industrial Associations, the California Council on Air and Water Waste Control, and the California Manufacturers Association, at a hearing in support of the State Water Pollution Control Act, stated that under this act, adopted in 1950, ". . . the greatest progress in the history of the state has been made towards controlling water pollution." He also stated that, whereas about $300 million had been invested in municipal facilities during the 7½ years of the life of the act, industry had invested about $250 million in its own facilities. This is in addition to paying a substantial portion of the $300 million invested in municipal facilities. The 1958 progress report of the California Water Pollution Control Board includes a statement typical of the situation in many states: "When the Water Pollution Control Board began operating early in 1950, many communities throughout the state were discharging untreated or inadequately treated sewage. Today, with few exceptions, the adverse conditions existing in 1950 have been satisfactorily corrected. Of even greater significance is the fact that in the past eight years every new major sewage or industrial waste system has been provided with adequate treatment or disposal facilities."

It is also refreshing to note that a number of state pollution control administrators, commenting on the questionnaire, pointed out, as did F. H. Waring of Ohio, that they ". . . have accomplished the desired results by in-plant changes and changes in processes, with a minimum of waste treatment plants." Such results require a mutual understanding between industrial management and regulatory officials, an understanding that must be further strengthened for continued progress in the years ahead.

5. Legislation for rapid amortization of industrial waste treatment costs.—Increasing interest is developing in proposed legislation, on federal and state levels, to encourage development of industrial waste treatment works by allowing rapid amortization of such expenditures for income tax purposes. This would allow quick writeoff of nonprofit waste treatment facilities for tax relief.

6. Progress in industrial waste research.—With increasing labor and material costs, research in waste conservation has become more attractive. Recent break-throughs in waste treatment at radically lower costs than previous conventional methods are stimulating further waste treatment research. Many unsolved problems beset the research worker today, and many knotty ones will come up tomorrow. Rapid acceleration of these research efforts is essential if industry is to continue to grow to meet the needs of increasing population and rising standard of living. The wastes research worker in industry, aided by other scientific disciplines available in his industry, and working closely with his counterparts in university and governmental research organizations, is today recognized as an important part of the industrial research team. This recognition in itself will lend impetus to industrial waste research in the years ahead.

7. Improvements in stream quality measurement.—The quality and the quantity of data on the chemical, biological, and hydraulic characteristics of streams have improved significantly during the past decade. Expanding on the studies conducted by state, local, and industrial organizations, the Water Quality Network organized by the U. S.

Public Health Service to monitor stream conditions may soon become a valuable source of information in determining whether stretches of streams are improving or regressing, and may also become a source of information for determining cause-and-effect relationships in stream quality. Concerning such cause-and-effect relationships, Enright (6), reporting on break-point chlorination experiences, states that "When the first of these six periods (of high break-point chlorination) struck (November 1951), we thought of industrial wastes. Others along the Ohio pursued the same thought. We had then about 2¾ yr of experience with the Ohio and its chlorine demand characteristics, and believed we knew something of them. Now, after 10 yr, we are more cautious, but do believe that these peaks are due principally to normal degradation products of nature with stream flows governing the intensity and duration." Accurate, meaningful stream quality measurements have been and will continue to be essential to sound progress in stream quality improvement.

8. *Municipal treatment of industrial wastes.*—There has been a growing sense of joint responsibility in the handling of industrial wastewaters within municipalities. This was brought out in a study conducted by the Subcommittee on Combined Treatment of Industrial and Municipal wastes of the Chemical Industry Advisory Committee of ORSANCO (4). Based on replies to a questionnaire concerning handling of industrial wastes, the committee came to the following conclusions: "Although impossible of reduction to a table or number, there was evident in the tone of the overwhelming majority of replies, a spirit of cooperation between municipality and industry in solving the industrial waste treatment problem. This might be considered the most important conclusion of the survey. Most of the municipalities surveyed accepted industrial wastes either without reservation or with only general prohibitions against materials harmful to the system or its function. Only 11 per cent of the respondents established fixed numerical limits on specific materials. Industry likewise was reported as generally willing to study and take care of real offenders. The two—municipality and industry—approached waste treatment as a common problem which they must both work to solve."

As both industries and municipalities are becoming more aware of their joint dependency, some unusual but altogether practical joint ventures are coming into being. A unique case is cited by Schrader (7) in which the city of South Charleston, W. Va., built a joint municipal-industrial wastewater treatment plant, designed by Union Carbide Chemicals Company and operated by a treatment company set up as a subsidiary of Union Carbide. This and many other, perhaps less unique, cases of successful municipal-industrial negotiations indicate a promising trend shaping the future.

Summary

Where does industry stand in water pollution control? In evaluating the past, industry can stand on the record—a record that shows substantial progress.

The greatest promise of the future is the increasing recognition of the need to integrate industrial waste management with production, with waste research a partner of process development.

The exchange of information and coordination of effort made possible through the National Technical Task Committee on Industrial Wastes, continues to stimulate effort in industrial wastes management. Because so much industrial wastes control involves in-plant waste conservation measures, progress must necessarily come from within the industrial framework, stimulated by careful, realistic evaluations

of stream quality and water uses developed by stream pollution control administrators.

Industry is responsive to the public interest, as demonstrated by the accelerated progress in industrial wastes control during the past decade. The trends shaping the future indicate that responsible industrial management will continue to recognize the part it must play in stream quality improvement.

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MONTHLY CONTRACT AWARDS—SEWAGE TREATMENT WORKS AND COLLECTING SEWERS AS REPORTED BY THE PUBLIC HEALTH SERVICE (MILLIONS OF DOLLARS)

Month	Treatment		Sewers		Total	
	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative
1960						
Jan.	27.2	27.2	20.6	20.6	47.8	47.8
Feb.	19.9	47.1	23.6	44.2	43.5	91.3
Mar.	36.4	83.5	24.9	69.1	61.3	152.6
Apr.	25.6	109.1	28.8	97.9	54.4	207.0
May	22.6	131.7	33.8	131.7	56.4	263.4
June	34.5	166.2	43.9	175.6	78.4	341.8
July	33.2	199.4	38.5	214.1	71.7	413.5
Aug.	23.6	223.0	29.7	243.8	53.3	466.8
Sept.	31.9	254.9	25.1	268.9	57.0	523.8
Oct.	29.0	283.9	26.7	295.6	55.7	579.5
Nov.	30.4	314.3	33.8	329.4	64.2	643.7
Dec.	44.7	359.0	30.0	359.4	74.7	718.4
1961*						
Jan.	24.4	24.4	22.4	22.4	46.8	46.8
Feb.	33.5	57.9	22.3	44.7	55.9	102.7
Mar.	47.1	105.0	30.1	74.8	77.2	179.9

* All data for the current year are provisional.

EXPERIMENTAL LAGOONING OF RAW SEWAGE AT FAYETTE, MISSOURI

Joe K. Neel, J. H. McDermott, and C. A. Monday, Jr.

Origin, development, and spread of raw sewage lagoons or stabilization ponds in the United States have been described and discussed in several articles (1) (2) (3) (4) (5) (6). Investigations (7) (3) (4) (5) involving the United States Public Health Service have concerned certain biotic relationships and general processes affecting treatment in facilities of this type. These studies also showed a dearth of information on basic principles and pointed out the need for controlled field-scale studies to resolve a number of fundamental considerations.

In 1956 the Public Health Service entered into an agreement with the Missouri Division of Health and the City of Fayette, Mo., for construction and controlled operation of stabilization ponds to be fed Fayette sewage. The Public Health Service and the Division of Health subsidized cost of the experimental ponds; the Service directed and conducted studies. Controlled operation began in May 1957.

The initial objectives were determination of the following:

1. Performance as judged by effluent quality and possible nuisance development.
2. Efficiency as related to loading rate and climatological variation.
3. The most favorable loading (pounds BOD/day/acre) for this location.

It was assumed that data acquired in realization of these objectives would permit additional insight into basic phenomena, processes, and relationships.

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Description

Fayette is situated in central Missouri, about midway between Kansas City and St. Louis, at an elevation of 640 ft above mean sea level. The 1950 population was 3,144, including approximately 400 resident students of Central College. The sewered population has been estimated at 2,700 and some seasonal variation coincides with college schedules. Municipal wastes include the normal small industries, laundries, slaughterhouses, and locker plants. Floor washings from a "pig parlor," or automatic hog feeding pen, were discharged to the municipal system during much of the period covered in this report (May 1957 to May 1958).

Treatment Facilities

The lagoon or "pond" installation is shown in Figure 1. Sanitary sewer lines (marked by heavy lines at upper left) end at a wet well, from which sewage is pumped up to the distributor shown in Figure 2. A bypass line extends from a manhole to the creek as indicated. The piping system diagrammed on the photograph allows selective division of the sewage load among the various units, series operation, etc. Sewage is apportioned to

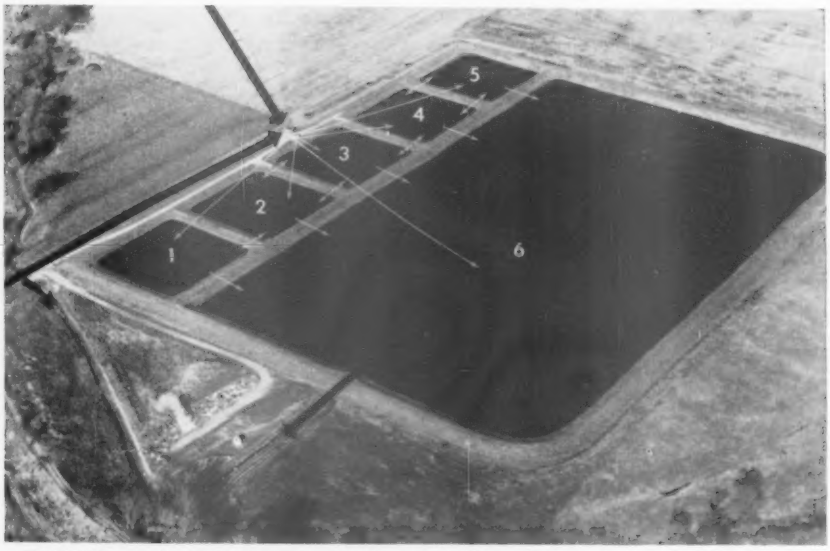

FIGURE 1.—Aerial view of Fayette lagoon facility. Raw sewage and outlet lines are shown by heavy black lines and bypass line by black arrow at left center. White lines indicate feed pipes from the distributor and intercell communications. Arrows show possible directions of flow. (Photo, courtesy *St. Louis Post Dispatch*.)

various units as desired by dividing flow off the conical distributor apron with movable partitions. It was necessary to install an annular orifice around the upper part of the cone to secure uniform distribution down the apron. Excess sewage passes through waste holes to the 15-acre lagoon.

The five small ponds are each 1 acre in area when filled to a depth of 5 ft, and ¾ acre each when liquid is 2½ ft deep. The minimum possible overflow level is 2½ ft; the maximum operational depth is about 6 ft. The large pond is 15 acres in area at its usual operating depth of 3 ft. It receives effluent from the small ponds and raw sewage not used in their loadings.

Methods of Study

The initial division of sewage to small units provided 5-day 20°C BOD loadings of 20, 40, 60, 80, and 100 lb/day/acre. Cells were maintained at a depth of 2½ ft and actual BOD loadings to the ¾-acre units were 15, 30, 45, 60, and 75 lb/day. Raw sewage load to the large cell, which also received effluent from the small units, was about 15 lb BOD/day/acre.

Raw sewage was composited over a 24-hr period with a device that withheld and delivered to a refrigerated container a small volume from the quantity delivered during each operation of one pump. All lagoon samples were grabs from the effluents, as were coliform samples from raw sewage. Analyses for temperature, pH, alkalinity, oxygen, BOD, nitrogen cycle, organic phosphorus, phosphate, chloride, detergent, coliform-type bacteria, and plankton were according to "Standard Methods" (8). Instruments for measurement of precipitation, evaporation, wind movement, and maximum and minimum air temperature were installed by the U. S. Weather Bureau in July 1957. Solar radiation was recorded on a clockwork pyrheliometer that had been rated against a standard Weather Bureau instrument. Most analyses were performed once or twice

a week. Oxygen was often measured daily, and on occasion several times a day. Plankton samples were collected at weekly and biweekly intervals.

Climatological Features

Monthly summaries of climatological data are given in Table I. Solar radiation measurements began in June 1957. Evaporation and wind records for May, June, and July are from a weather station 10 miles south at New Franklin, Mo. Evaporation was not measured over the period November–March.

Maximum average monthly temperature occurred in July and the minimum in February. The highest average temperatures did not occur during the month with highest listed average solar radiation; but the pyrheliometer was inoperative over the period June 27–July 9, inclusive, and the average value listed for July is probably low. Records for December are complete, and only four days are lacking for February, so it would appear that solar radiation decline is but one of several factors contributory to low temperature.

Total precipitation over the 13-month period exceeded evaporation from ponds by 4.18 in.; greatest precipitation occurred in May and June, and the highest rate of evaporation was in June and July. December and March were the windiest months, and July and August the calmest.

Raw Sewage

Quantity

Sewage volume was measured by timing daily pump operation. Average daily volume varied from 0.159 mgd in August 1957 to 0.276 mgd in May 1958. The over-all mean was 0.216 mgd (Table II). The sewers allow appreciable infiltration.

Hydraulic loadings to various ponds are given in Table III. Volumes to Cells 1–5 are given in increments of 7,000 gal, as the calculated diversion to Cell 1 was 6,985 gpd.

Sewage flow suffered a number of interruptions occasioned by pump failures and their inadequacy to handle large amounts of storm water. Sewage

FIGURE 2.—Sewage distributor. An annular orifice was later installed around the upper cone and the entire assembly then enclosed in a frame building.

TABLE I.—Monthly Summaries of Climatological Data

Month	Air Temperature (°F)			Avg Solar Radiation (langleys/day)	Precipitation (in./mo)	Evaporation from Ponds (in./mo)	Wind (miles/mo)
	Avg Max	Avg	Avg Min				
1957							
May	74.9	64.1	53.3	—	5.00	4.97	2,246
June	83.1	73.1	63.1	553	5.10	4.85	1,624
July	89.4	79.3	69.2	550	4.43	5.35	1,437
Aug.	88.4	76.4	64.3	515	1.02	5.18	964
Sept.	79.0	65.6	52.1	388	2.05	3.32	2,023
Oct.	65.8	53.7	41.6	286	4.93	2.80	2,925
Nov.	51.1	41.6	32.1	198	1.70	—	3,280
Dec.	48.7	38.0	27.2	161	2.19	—	4,173
1958							
Jan.	38.5	29.5	20.5	198	1.63	—	3,559
Feb.	32.6	23.2	13.8	276	1.20	—	3,682
Mar.	42.9	36.6	30.2	320	2.10	—	4,396
Apr.	63.8	53.1	42.4	446	1.50	3.91	3,809
May	75.8	64.4	52.9	552	6.32	4.61	2,246
Totals	—	—	—	—	39.17	34.99	36,364

was completely bypassed 13 days and partially excluded during 20 days of the 13-month period. Most trouble occurred in March 1958, when it was necessary to bypass 5 days and partially divert on 11 days.

Quality

All analyses except coliform-type bacteria were performed on 24-hr composites and therefore do not indicate daily variation or oxygen and temperature measurements. Monthly and overall averages and pH ranges are indicated in Table IV. Organic phosphorus and organic nitrogen values represent the differences between total values and phosphate and ammonia, respectively. Syndet and hardness analyses were discontinued when interfering substances developed in pond water.

Preliminary analyses in February and March 1957 indicated an average BOD load of 480 lb/day, and adjustment of distributor to give the planned loads of Table III was on this basis. Average BOD concentration over the 13-month period was 274 mg/l, and mean load 457 lb/day.

TABLE II.—Average Daily Raw Sewage Flow

Month	Flow
1957	(mgd)
May	0.231
June	0.186
July	0.169
Aug.	0.159
Sept.	0.178
Oct.	0.207
Nov.	0.212
Dec.	0.216
1958	
Jan.	0.231
Feb.	0.242
Mar.	0.245
Apr.	0.270
May	0.276
Avg.	0.216

Pond Characteristics

Appearance and General Conditions

Bottoms and dikes were formed of compacted clay soils native to the area. These soils proved to be satisfactorily resistant to infiltration, but undiscovered agricultural tile fields drained water from Cells 1, 2, and 6 at the be-

TABLE III.—Average Daily Raw Sewage Load to Lagoons

Cell	Area (acres)	Depth (ft)	Volume (gpd)		Theoretical Detention (days)	BOD (lb)			
						Planned		Realized	
			Per Cell	Per Acre		Per Cell	Per Acre	Per Cell	Per Acre
1	0.75	2.5	7,000	9,000	87	15	20	15.2	20.3
2	0.75	2.5	14,000	18,000	44	30	40	30.4	40.5
3	0.75	2.5	21,000	28,000	29	45	60	45.6	60.8
4	0.75	2.5	28,000	37,000	22	60	80	60.8	81.1
5	0.75	2.5	35,000	47,000	17	75	100	76.0	101.3
6	15.00	3.0	111,000	7,000	68	255	16	229.0	15.3

ginning of operations in November 1956. Lines leading into lagoon bottoms were eventually plugged and no detectable loss to ground occurred after May 1957. Dikes were seeded during the fall of 1956 and became well-covered with vegetation during the summer of 1957. Fescue grass became the dominant growth in early summer 1958. Dikes were noticeably eroded by rains prior to establishment of the vegetative cover.

Appearance of Phytoplankton

Pond 6 developed populations of algae shortly after introduction of sewage. Earliest arrivals were *Chlamydomonas* and *Euglena*, both of which grew attached to bottoms and suspended in shallow water. Green color, once developed, was generally maintained in all ponds until February 1958, when water in some cells turned gray or colorless. Initial buildup of operational volume in Cell 6 posed no problems, as algae appeared when water was about 1 in. deep and the bottom but partially covered. Units 1–5 developed noticeable algae on December 28, 1956. Their filling was frequently interrupted.

Algal Mats

Planktonic and bottom-adhering (benthic) algae were the only types present until June 1957 when floating blue-

TABLE IV.—Raw Sewage; Average Analysis Results

Month	pH	Total Alk. (mg/l)	BOD (mg/l)	Org. P (mg/l)	PO_4 (mg/l)	Org. N (mg/l)	NH_3—N (mg/l)	NO_2—N (mg/l)	NO_3—N (mg/l)	Chloride (mg/l)	Detergent (mg/l)	Coliform (MPN)
1957												
May	7.1–7.3	224	254	12.9	25.7	84.2	19.5	0.01	0.2	60	1.1	23,532,857
June	6.9–7.2	256	314	12.8	30.2	115.3	26.4	0.00	0.04	51	1.1	38,380,000
July	6.8–7.2	240	279	15.2	38.9	134.1	32.4	0.00	0.06	—	1.9	43,500,000
Aug.	6.6–7.2	246	266	13.5	33.1	133.5	31.1	0.00	0.06	55	1.3	25,300,000
Sept.	6.6–7.3	241	308	10.6	26.4	136.3	32.5	0.00	0.2	57	1.1	31,250,000
Oct.	6.9–7.2	222	280	11.7	29.3	105.2	26.0	0.00	0.3	60	1.0	37,100,000
Nov.	7.0–7.2	260	266	15.5	39.8	189.1	41.8	0.00	0.25	69	0.5	68,000,000
Dec.	7.2	276	310	15.7	38.6	186.0	46.5	0.00	0.3	—	—	68,000,000
1958												
Jan.	7.0–7.2	282	270	18.0	39.0	158.5	39.0	0.00	0.1	—	—	43,000,000
Feb.	6.9–7.2	290	223	7.0	21.4	107.2	27.1	0.00	0.1	69	—	—
Mar.	7.1–7.2	279	252	8.7	26.7	131.3	35.7	0.00	0.0	—	—	48,433,333
Apr.	7.0–7.6	241	195	4.4	16.0	100.2	24.0	0.00	0.1	—	—	15,766,667
May	7.0–7.1	262	252	12.3	31.3	99.3	26.0	0.00	0.1	—	—	46,766,667

green mats, largely composed of *Oscillatoria* and *Phormidium*, appeared in some cells and endured for varying periods of time. They seemingly developed from or on wind-concentrated patches of detached benthic algae (usually *Phormidium*) that often floated to the surface. The later growths bound these patches together, often forming a surface firm enough to support small sandpipers. Coloration usually involved a light blue or whitish background with numerous blue-green, brown, green, and black splotches or bands. Green patches examined were composed of *Chlamydomonas* and/or *Euglena*, but other organisms probably occur. Mats were most frequently wind driven to the south banks of those lagoons in which they developed, but they moved from shore to shore with changes in wind direction. Surface disturbances by wind action were not observed to destroy or sink the mats, but they were soon broken up by moderate or heavy rains. However, they re-formed within a few days in hot weather. Mats emitted characteristic pigpen odors that were frequently detectable for distances of 20 to 50 ft.

Greatest mat development was attained in Cell 6 (Figure 3), and often involved areas of an acre or more. Cells 1 and 2 frequently had as much as 20 per cent of their surfaces so occupied; but mats occurred less frequently in Cells 3, 4, and 5, and when present were restricted to narrow marginal strips. Loadings in excess of 60 lb BOD/day/acre maintained dense plankton populations that probably deprived bottom growths of needed light.

Ice Cover

Thin ice was first noted in the early morning on November 9, 1957. Weak partial covers of ice that endured a few hours or all day were common from then until December 11, when all cells became covered except over inlets. This condition persisted until January 10, 1958, when open channels developed from inlets to outlets in Cells 3, 4, and 5. Melting continued and ice left all units on January 16. It reappeared on January 22 and developed complete covers (except for inlet areas) on January 23; final thawing began February 23 and all surfaces were ice-free on February 26. In response to greater

FIGURE 3.—Blue-green algal mat in southeast corner of Cell 6.

quantities of warm raw sewage, Cells 4 and 5 thawed more rapidly than other ponds and lost all ice on February 24. Open water extended from inlets toward outlets on February 4, but did not quite reach the latter openings, and partial channels refroze on February 6. Snow covered the ice from January 23 until early February, and from February 11 to February 22. Greatest thickness of ice (February 16) was 3½ in.

Open strips from inlets to outlets in Cells 3, 4, and 5, in mid-January, and from inlets to near outlets in early February, resulted from short-circuiting seemingly induced by strong northwest winds that melted ice with warm water pushed from openings above inlets. Such direct short-circuiting was apparently possible only with ice cover, as no evidences of such action were found when surfaces were open.

Color

Water maintained a light to dark green or yellow-green color in all ponds from start of operation in fall of 1956 until ice cover appeared during the 1957–1958 winter. Rains carried quantities of silt into the sewers and gray streaks or layers usually occurred in the 1-acre ponds after each storm and in Cell 6 after prolonged downpours. Cell 4 lost its green color and turned gray after ice formed in January; others varied from light to dark green in color when ice melted on February 24. Cell 5 became gray on February 28, but all others remained green. Cell 4 became green again on March 24, and Cell 5 on March 25, 1958.

Odors

Other than those from blue-green algal mats, odors were absent until ice cover began to melt on February 23, 1958. At that time, a slight sulfide scent was traced to Cells 4 and 5. This odor became stronger on February 26 and endured downwind for a distance of 550 ft. Cell 3 was then a contributor. On February 28, Cell 3 had no scent; but sulfides leaving Cells 4 and 5 were still detectable for 550 ft. On March 2, odors could be detected about 50 ft from the margins of Cells 3, 4, and 5. This condition continued until Cell 3 lost its odor on March 9, Cell 4 on March 24, and Cell 5 on March 26.

Pond Analyses

Physical Features

Temperature

Lagoon surfaces showed a general uniformity of temperature, and individual monthly averages never differed as much as 1°C. Maximum average temperatures occurred in July and minimums in December, January, and February. The range of monthly averages is given in Table V.

Chemical Features

Average monthly levels, pH ranges, and monthly maximum and minimum oxygen concentrations and per cent saturation are listed by cell number in Table V. All analyses represent surface water as it entered the outlet pipe; tests made in Cells 3, 4, and 5 were affected by sewage when short-circuiting developed January 10 and February 4.

Hydrogen Ion Concentration

As is characteristic of most natural waters with phytoplankton, pH levels clearly indicated the predominance of photosynthesis or respiration-decomposition. No soluble normal carbonate (CO_3) occurred in waters entering the ponds; hence, (*a*) pH values above 8.0 were produced by a photosynthetic rate that demanded more carbon dioxide than quantities furnished by respiration and decomposition, and (*b*) pH levels below 8.0 indicated failure of photosynthesis to utilize completely amounts of CO_2 so produced. In the first case, bicarbonate $Ca(HCO_3)_2$ was broken down to provide CO_2, and the by-product $CaCO_3$ (normal carbonate) elevated pH fairly well in proportion to photosynthetic intensity, despite

TABLE Va.—Cell 1, Average Effluent Analysis Results
(Loading 20 lb BOD/day/acre)

Month	Temp. (°C)	pH	CO_2 Alk. (mg/l)	HCO_3 Alk. (mg/l)	O_2 (mg/l)			O_2 Sat. (%)			BOD (mg/l)	Org. P (mg/l)	PO_4 (mg/l)	Org. N (mg/l)	NH_3—N (mg/l)	NO_3—N (mg/l)	Chloride (mg/l)	Detergent (mg/l)	Coliform (MPN)
					Avg	Max	Min	Avg	Max	Min									
1957																			
May	24	7.8– 9.2	—	—	21	26	6	258	310	66	35	—	—	—	—	0.2	45	1.1	22,017
June	29	8.4–10.5	67	80	10	20	7	135	263	90	32	4.6	11.7	6.7	9.9	0.2	52	2.1	13,640
July	33	8.8–11.4	122	46	20	41	1	281	569	16	44	2.7	6.9	8.1	7.5	0.1	55	1.3	17,500
Aug.	29	8.6– 9.6	54	101	17	38	5	222	494	62	43	3.7	9.2	6.3	6.2	0.2	49	1.2	17,980
Sept.	22	8.7– 9.8	76	85	16	26	11	181	307	125	45	1.6	4.3	4.0	3.9	0.0	51	1.5	18,750
Oct.	16	8.7–10.5	86	80	18	27	10	191	283	102	36	1.9	4.3	—	4.3	0.1	47	1.3	10,810
Nov.	8	8.5– 9.1	32	131	14	18	9	117	150	74	33	2.2	5.7	4.6	5.2	0.1	51	1.3	6,800
Dec.	3	7.6– 8.6	12	175	8	12	3	62	90	21	34	0.6	3.8	5.0	5.0	0.0	—	—	3,950
1958																			
Jan.	3	8.0– 9.2	32	170	19	24	10	140	174	73	27	2.0	4.9	5.4	5.5	0.0	—	—	4,300
Feb.	2	7.9– 8.6	10	188	10	15	8	72	109	58	28	1.0	3.9	4.8	4.9	0.0	54	—	—
Mar.	6	8.4– 9.6	50	127	20	30	9	164	245	75	31	2.1	5.8	5.6	5.9	0.0	—	—	30,100
Apr.	14	7.6– 8.9	14	164	11	26	3	109	260	25	31	2.0	5.5	6.7	6.7	0.0	—	—	4,300
May	26	8.0– 9.5	58	131	20	30	3	242	368	36	28	2.3	5.9	4.6	4.8	0.0	—	—	5,967

TABLE Vb.—Cell 2, Average Effluent Analysis Results
(Loading 40 lb BOD/day/acre)

Month	Temp. (°C)	pH	CO_3 Alk. (mg/l)	HCO_3 Alk. (mg/l)	O_2 (mg/l)			O_2 Sat. (%)			BOD (mg/l)	Org. P (mg/l)	PO_4 (mg/l)	Org. N (mg/l)	NH_3—N (mg/l)	NO_3—N (mg/l)	Chloride (mg/l)	Detergent (mg/l)	Coliform (MPN)
					Avg	Max	Min	Avg	Max	Min									
1957																			
May	24	7.3– 9.1	—	—	13	26	Tr.	152	312	5	31	—	—	—	—	0.2	49	1.1	50,766
June	29	8.8– 9.3	74	81	10	13	9	133	167	114	36	4.7	11.0	9.0	12.9	0.3	57	2.3	28,120
July	33	8.1–11.0	134	38	19	35	0	258	481	0	46	3.8	8.7	10.0	9.8	0.1	47	1.4	27,557
Aug.	29	8.0– 9.6	52	100	17	37	3	221	486	35	37	3.5	8.6	7.3	7.3	0.04	52	1.3	11,640
Sept.	22	8.9–10.2	120	30	15	18	10	179	205	114	56	2.4	6.1	6.2	6.2	0.1	54	1.6	32,700
Oct.	16	8.0–10.2	47	110	17	27	8	173	276	85	47	—	7.0	—	5.7	0.1	49	1.2	13,133
Nov.	8	7.9– 9.1	10	178	11	16	7	89	134	58	33	1.9	5.5	4.6	4.9	0.0	52	1.2	13,475
Dec.	3	7.2– 8.4	3	226	5	10	0	38	77	0	37	0.4	5.2	5.7	5.8	0.0	—	—	6,800
1958																			
Jan.	3	7.6– 8.5	14	197	12	14	10	89	107	72	32	2.6	6.5	5.7	5.7	0.0	—	—	3,600
Feb.	1	8.0– 8.8	15	196	14	19	9	103	136	66	40	1.9	9.4	8.5	8.6	0.0	60	—	—
Mar.	5	8.5– 9.6	52	117	21	27	11	161	219	85	34	2.1	7.2	5.8	6.9	0.0	—	—	43,000
Apr.	14	8.6– 9.6	48	112	20	29	12	194	291	114	32	2.1	5.2	5.3	5.3	0.0	—	—	6,800
May	27	8.7– 9.5	60	116	20	28	6	245	352	72	33	2.2	5.5	5.2	5.5	0.0	—	—	4,300

TABLE Vc.—Cell 3, Average Effluent Analysis Results
(Loading 60 lb BOD/day/acre)

Month	Temp. (°C)	pH	CO_2 Alk. (mg/l)	HCO_3 Alk. (mg/l)	O_2 (mg/l)			O_2 Sat. (%)			BOD (mg/l)	Org. P (mg/l)	PO_4 (mg/l)	Org. N (mg/l)	NH_3—N (mg/l)	NO_3—N (mg/l)	Chloride (mg/l)	Detergent (mg/l)	Coliform (MPN)
					Avg	Max	Min	Avg	Max	Min									
1957																			
May	24	7.7– 9.2	—	—	13	27	4	159	317	43	38	—	—	—	—	0.2	54	1.5	—
June	29	8.3–10.9	146	0	14	22	Tr.	180	289	1	50	3.2	7.7	10.2	9.5	0.2	58	1.4	38,380
July	33	8.8–11.7	152	11	18	34	2	250	475	32	37	5.3	13.3	9.9	9.4	0.1	47	1.4	39,514
Aug.	29	7.9–10.2	62	109	16	34	2	204	444	30	53	4.5	11.4	11.6	11.6	0.1	53	1.6	7,440
Sept.	22	8.4–10.5	102	69	17	27	12	197	312	134	57	3.6	9.0	7.4	7.3	0.1	52	1.5	19,260
Oct.	16	7.4– 9.3	28	142	16	26	6	167	267	57	55	2.5	6.7	4.8	4.7	0.1	49	1.2	17,767
Nov.	8	7.8– 9.1	19	170	12	17	6	100	143	54	44	4.7	11.8	16.3	5.1	0.2	56	1.2	9,300
Dec.	3	7.7– 8.5	6	219	9	11	6	70	84	44	43	2.0	7.2	10.5	3.4	0.0	—	—	6,800
1958																			
Jan.	3	7.2– 8.0	0	224	6	9	3	48	66	24	75	6.5	16.3	13.1	13.1	0.1	—	—	43,000
Feb.	3	7.5– 8.0	0	230	3	10	0	23	77	0	50	2.8	14.0	12.3	12.5	0.2	64	—	—
Mar.	6	7.3– 9.4	35	162	17	37	0	140	302	0	48	2.9	9.9	10.4	10.9	0.0	—	—	53,333
Apr.	14	8.3– 9.4	34	139	18	24	9	173	233	88	42	2.0	5.5	5.6	5.6	0.0	—	—	48,650
May	22	7.9– 9.8	46	135	18	35	2	201	403	25	37	3.7	9.4	7.7	7.7	0.0	—	—	20,100

TABLE Vd.—Cell 4, Average Effluent Analysis Results
(Loading 80 lb BOD/day/acre)

Month	Temp. (°C)	pH	CO_2 Alk. (mg/l)	HCO_3 Alk. (mg/l)	O_2 (mg/l)			O_2 Sat. (%)			BOD (mg/l)	Org. P (mg/l)	PO_4 (mg/l)	Org. N (mg/l)	NH_3—N (mg/l)	NO_3—N (mg/l)	Chloride (mg/l)	Detergent (mg/l)	Coliform (MPN)
					Avg	Max	Min	Avg	Max	Min									
1957																			
May	24	7.5– 9.2	—	—	11	24	4	135	277	44	34	—	—	—	—	0.2	56	1.2	63,333
June	29	8.2–10.2	114	43	11	19	2	147	245	25	54	2.4	6.1	7.2	7.1	0.2	60	1.5	39,520
July	33	8.4–11.4	142	25	18	39	0	243	505	0	45	3.0	7.4	5.5	5.3	0.1	59	1.5	39,800
Aug.	29	7.8– 9.2	40	125	15	34	2	196	439	19	57	5.0	12.6	9.6	9.7	0.1	55	1.6	16,180
Sept.	22	8.3– 9.8	66	198	17	23	4	191	270	51	52	3.2	8.1	5.8	5.7	0.1	52	1.2	12,300
Oct.	16	7.8–10.2	42	131	16	25	9	171	258	91	51	2.6	6.7	7.2	7.1	0.1	51	1.3	10,817
Nov.	7	7.3– 8.5	3	202	9	13	3	78	109	25	29	2.3	5.8	6.5	6.5	0.1	53	1.4	14,250
Dec.	3	7.4– 8.5	3	254	8	10	6	56	72	42	37	0.4	5.9	5.1	5.1	0.0	—	—	26,150
1958																			
Jan.	3	6.9– 8.0	0	227	5	8	1	40	59	10	71	5.5	14.0	10.4	10.4	0.1	—	—	43,000
Feb.	3	7.3– 7.8	0	240	1	7	0	10	51	0	63	4.2	14.7	12.2	12.2	0.2	63	—	—
Mar.	6	7.3– 8.8	6	214	4	25	0	33	208	0	57	3.9	12.9	13.5	14.6	0.0	—	—	93,000
Apr.	15	8.1– 9.3	26	100	19	27	12	190	267	122	42	3.2	7.1	8.8	8.8	0.1	—	—	23,650
May	27	7.6– 9.2	30	160	14	33	0	173	416	0	40	4.9	12.0	12.2	12.2	0.0	—	—	26,150

TABLE Ve.—Cell 5, Average Effluent Analysis Results
(Loading 100 lb BOD/day/acre)

Month	Temp. (°C)	pH	CO_3 Alk. (mg/l)	HCO_3 Alk. (mg/l)	O_2 (mg/l)			O_2 Sat. (%)			BOD (mg/l)	Org. P (mg/l)	PO_4 (mg/l)	Org. N (mg/l)	NH_3—N (mg/l)	NO_3—N (mg/l)	Chloride (mg/l)	Detergent (mg/l)	Coliform (MPN)
					Avg	Max	Min	Avg	Max	Min									
1957																			
May	24	7.6– 9.1	—	—	16	26	5	186	306	64	39	—	—	—	—	0.2	48	1.6	52,286
June	29	8.4–10.4	90	71	9	17	Tr.	114	221	5	39	4.2	9.3	8.0	8.1	0.1	59	1.6	56,260
July	33	8.7–11.3	130	42	17	41	0	242	571	0	41	3.2	8.0	11.6	10.6	0.1	56	1.6	41,833
Aug.	29	8.5– 9.6	54	89	14	30	5	186	388	60	53	3.6	9.1	8.7	8.4	0.1	53	1.7	30,780
Sept.	22	8.0– 9.4	41	128	12	20	5	136	229	60	51	4.3	11.0	6.6	6.5	0.1	53	0.9	18,867
Oct.	16	7.8–10.7	54	116	19	32	11	193	334	113	50	2.0	5.1	5.5	5.5	0.0	—	1.3	17,700
Nov.	7	7.6– 8.8	14	183	10	16	5	83	131	42	38	2.9	7.2	5.9	6.2	0.1	55	2.3	6,325
Dec.	3	7.8– 8.7	7	218	9	12	7	71	92	50	40	1.9	6.9	6.0	6.0	0.0	—	—	6,800
1958																			
Jan.	3	7.0– 8.2	3	215	9	12	4	64	93	32	42	2.9	7.3	5.5	5.5	0.0	—	—	9,300
Feb.	3	7.4– 8.0	0	235	3	10	0	20	72	0	63	3.0	13.2	12.8	12.7	0.2	63	—	—
Mar.	6	7.3– 7.6	0	237	1	8	0	8	64	0	66	4.5	14.4	12.9	14.2	0.0	—	—	477,667
Apr.	15	7.5– 9.5	30	153	16	28	5	163	282	52	40	2.9	7.2	6.1	6.1	0.0	—	—	9,300
May	24	8.2– 9.3	38	145	14	23	0	172	279	0	51	5.7	14.3	12.5	12.9	0.0	—	—	46,767

TABLE Vf.—Cell 6, Average Effluent Analysis Results
(Loading 16+ lb BOD/day/acre)

Month	Temp. (°C)	pH	CO_3 Alk. (mg/l)	HCO_3 Alk. (mg/l)	O_2 (mg/l)			O_2 Sat. (%)			BOD (mg/l)	Org. P (mg/l)	PO_4 (mg/l)	Org. N (mg/l)	NH_3—N (mg/l)	NO_3—N (mg/l)	Chloride (mg/l)	Detergent (mg/l)	Coliform (MPN)
					Avg	Max	Min	Avg	Max	Min									
1957																			
May	24	7.7	—	—	5	6	4	56	68	51	20	—	—	—	—	0.2	55	1.1	43,000
June	29	7.9– 9.1	36	132	7	10	3	90	124	34	35	4.1	9.8	11.6	11.6	0.2	53	1.5	56,260
July	33	8.0–10.0	68	101	8	19	1	119	258	17	28	4.3	8.1	12.5	9.8	0.1	46	1.2	17,840
Aug.	29	7.8– 8.9	14	159	6	9	2	75	120	25	32	3.6	9.0	6.2	6.1	0.0	48	1.2	5,815
Sept.	22	7.9– 9.2	32	142	10	16	4	115	186	49	42	2.4	6.2	3.6	3.6	0.0	53	1.2	8,225
Oct.	16	7.8– 9.1	14	162	10	14	4	100	148	46	34	2.5	6.2	5.4	5.4	0.1	49	1.2	11,650
Nov.	8	7.8– 9.1	28	151	12	16	6	103	140	55	31	1.3	—	3.0	2.9	0.1	50	1.8	4,900
Dec.	3	8.8– 9.5	42	143	16	18	13	112	135	99	30	—	4.6	5.5	5.5	0.1	—	—	9,300
1958																			
Jan.	2	9.0– 9.3	46	146	21	25	16	157	183	117	22	1.5	3.7	4.4	4.5	0.0	—	—	3,600
Feb.	3	8.8– 9.2	40	149	22	31	14	163	234	101	27	1.4	5.8	5.4	5.4	0.0	51	—	—
Mar.	7	8.7– 9.4	54	105	20	26	14	165	214	115	29	1.9	5.8	6.1	4.0	0.0	—	—	10,867
Apr.	14	8.8– 9.3	46	108	17	26	10	164	255	92	27	1.5	4.7	3.9	3.9	0.0	—	—	430
May	21	8.3– 9.6	42	136	13	19	2	149	210	26	29	2.4	5.8	4.6	4.7	0.0	—	—	5,733

losses to precipitation. In the second case, CO_2 arising from decomposition and respiration converted $CaCO_3$ back to $Ca(HCO_3)_2$, frequently combining with precipitated CO_3, and lowered pH below 8.0 when all CO_3 was utilized and free CO_2 began to accumulate. These reactions also influenced alkalinity and hardness.

Photosynthesis was the dominant process in Cells 1 and 2 during all months except December. Decomposition-respiration was dominant in Cell 3 in January and February; in Cell 4 from November to March; and in Cell 5 in February and March. In Cell 6, decomposition-respiration was dominant only in May 1957; photosynthetic influences were quite pronounced over the period December–April, when they were least evident or lacking in other units. Diurnal variation in pH that accompanies changing rate of photosynthesis is described at the end of the section on alkalinity.

Alkalinity

Alkalinity concentration is also controlled, within limits permitted by source of supply, by photosynthesis and decomposition-respiration. Photosynthesis decreases alkalinity by producing weakly soluble $CaCO_3$ that tends to precipitate; decomposition and respiration increase alkalinity by bringing lost normal carbonate back into solution as $Ca(HCO_3)_2$.

Table V indicates CO_3 and HCO_3 alkalinity. Some variation may be ascribed to changes in raw sewage (refer to Table IV) and level of alkalinity in the ponds may not always exactly reflect degree of photosynthesis and/or decomposition-respiration. It should also be borne in mind that solubility of CO_3 varies with temperature.

In Cells 1 and 2, some CO_3 was produced each month, although CO_2 formation equalled or exceeded it over the month of December. Cells 3, 4, and 5 produced no CO_3 during those months with zero values for CO_3 alkalinity, when it may be assumed that limited photosynthetic activity was inadequate to utilize current CO_2 evolution. Cell 6 lacked CO_3 only during May 1957; it enjoyed a near maximum rate of production in winter and early spring when other ponds were at or approaching their minima for the 13-month period. Carbonate alkalinity frequently exceeded bicarbonate alkalinity during more active seasons of photosynthesis (Table V). Bicarbonate alkalinity did not occur in June samples from Cell 3.

Measurements made July 18 and 19, 1957, show certain chemical reactions to changing rate of photosynthesis (Table VI) over a 28-hr period. The various cells differed in their degree of response, but they all showed the same diurnal pattern (that is, a buildup of pH, carbonate alkalinity, and oxygen, from early morning until late afternoon, and declines during the hours of darkness). Bicarbonate alkalinity decreased with continuing daylight, reaching zero values in all cells except 6, and increased during the night. Photosynthetic effects on chemistry grew with increasing light intensity and passage of time. They ceased with the coming of darkness; respiration and decomposition could then alter chemistry with unopposed CO_2 production. Alkalinity transformation during daylight hours indicates the extent of dominance exerted by photosynthesis. Absence of this process at night allows conservation of alkalinity and carbon dioxide as newly produced CO_2 is able to react with CO_3 to rebuild supplies of soluble carbonate ($Ca(HCO_3)_2$) and so escape loss from diffusion to the atmosphere.

Biochemical Oxygen Demand

Previous studies (3) (7) (9) (10) (11) have indicated various pitfalls attendant to BOD measurement of algae-laden waters or effluents. Respiration of algae increases oxygen consumption in samples incubated in darkness, and their photosynthesis may be expected

TABLE VI.—Diurnal Variation Reflecting Changing Photosynthetic Intensity

Date (July 1957)	Time	Cell 1					Cell 2					Cell 3				
		Temp. (°C)	pH	CO_2 Alk. (mg/l)	HCO_3 Alk. (mg/l)	O_2 (mg/l)	Temp. (°C)	pH	CO_2 Alk. (mg/l)	HCO_3 Alk. (mg/l)	O_2 (mg/l)	Temp. (°C)	pH	CO_2 Alk. (mg/l)	HCO_3 Alk. (mg/l)	O_2 (mg/l)
18	6:00 AM	29	9.4	46	153	6	29	8.1	0.4	165	0	29	9.6	84	80	9
	11:00 AM	31	10.8	64	124	20	31	9.9	84	104	11	31	10.3	190	0	8
	3:00 PM	32	11.3	152	0	24	32	10.4	202	0	21	32	10.9	190	0	19
	7:30 PM	32	11.4	160	0	30	32	10.6	—	—	25	32	10.5	160	0	20
19	10:00 AM	31	9.8	126	59	15	31	9.1	48	149	15	31	9.6	88	82	13
Date (July 1957)	Time	Cell 4					Cell 5					Cell 6				
		Temp. (°C)	pH	CO_2 Alk. (mg/l)	HCO_3 Alk. (mg/l)	O_2 (mg/l)	Temp. (°C)	pH	CO_2 Alk. (mg/l)	HCO_3 Alk. (mg/l)	O_2 (mg/l)	Temp. (°C)	pH	CO_2 Alk. (mg/l)	HCO_3 Alk. (mg/l)	O_2 (mg/l)
18	6:00 AM	29	8.7	38	157	Tr.	29	8.9	36	144	2	29	8.6	30	143	3
	11:00 AM	31	10.4	—	—	19	31	10.8	140	22	24	31	9.7	138	16	7
	3:00 PM	32	11.3	152	0	29	32	11.3	162	0	33	32	10.0	144	6	11
	7:30 PM	32	—	—	—	32	32	—	—	—	32	32	—	—	—	14
19	10:00 AM	31	9.6	106	69	11	31	9.5	102	88	19	—	8.9	42	137	4

to increase oxygen concentration if exposure to light is allowed. Filtering will remove algae, but will also take out particulate non-living organic matter whose oxygen demand is a valid part of BOD. Alternation of light and dark periods during incubation has been found to mask or partially obscure oxygen consumption.

It has been suggested that waters containing actively photosynthesizing phytoplankton have no BOD or minus BOD's if oxygen is maintained above the saturation level. This view may appear justified, especially if supersaturated levels are maintained overnight, but it may lead to the erroneous assumption that supersaturation represents complete oxidation or stabilization of waste organic matter. It appears wise at this time to recognize all known variables and actions that cast doubt on the applicability of BOD measurement of stabilization pond effluents, but yet acknowledge that the analysis in some degree reflects a residual of organic matter that may be used provisionally as an indication of treatment efficiency.

Average effluent BOD's (Table V) showed some relationship to load, with a major increase between 40 and 60 lb BOD/day/acre (Cells 2 and 3); however, there were no significant differences in averages among loadings ranging from 60 to 100 lb BOD/day/acre (Cells 3, 4, and 5). Cells 3 and 4 showed marked increases in January and February 1958, and Cell 5 in February, that were evidently occasioned by short-circuiting of raw sewage directly from inlet to outlet. Cells 3, 4, and 5 lost all oxygen under ice cover in February and remained devoid of oxygen for a number of days after ice melted in early March. Cell 3 concentrations in February and March were not significantly different from those noted in summer of 1957, and assignment of these values, particularly those of March, to unstabilized organic matter instead of algae appears questionable. In Cells 4 and 5, unaltered or slightly changed sewage components were involved in March concentrations.

Highest BOD's, except those referable to short-circuiting of raw sewage, were usually present when oxygen saturation was near its recorded peaks. Maximum saturations in Cells 3, 4, and 5 in July were contemporary to a noticeable BOD decline, but an increase was evident then in Cells 1 and 2. Measurable oxygen represents a momentary surplus and concentration is not always indicative of maximum photosynthetic rate (see discussion under oxygen section). Nevertheless, algae were involved in the majority of higher BOD concentrations, and were directly associated with average monthly levels as high as 57 mg/l. BOD's that were mainly due to unoxidized or unstabilized sewage elements were not much greater; oxygen demands of this nature were most pronounced in Cell 3 in January and February, and in Cells 4 and 5 in February and March. Cell 4 was affected by photosynthesis in March, and its average BOD was less than in February. It is possible that the fall in BOD concentration that occurred in Cells 3, 4, and 5 in November and December coincided with a decline in algal activities.

Oxygen

Photosynthesis appeared necessary for any prolonged maintenance of aerobic conditions. In summer months, oxygen consumption usually approached, equaled, or exceeded its production on a 24-hr basis; and an oxygen "pulse" was a normal daily phenomenon. All low or zero values shown during seasons when average values were in supersaturated ranges represent samples taken at or near daily ebbs, and maximum saturation levels usually represent conditions at or near daily maxima (Table V). Characteristic oxygen pulses, accompanying diurnal pH, and alkalinity variation, are given in Table VI. As indicated, time of analysis is all-important in evaluation of maximum photosynthetic rate.

In stabilization ponds and other waters heavily laden with algae, measurable oxygen largely represents photosynthetic production minus (*a*) consumption by decomposition and respiration and (*b*) loss by diffusion to the atmosphere after supersaturation is reached. In view of the rapid declines to zero values that occurred when lagoon photosynthesis was interrupted by daily or seasonal factors, it is apparent that with these loadings oxygen absorption from the atmosphere rarely if ever supplied more than a fraction of the decomposition-respiration demands. Hence, it may be assumed that measurable oxygen generally owed its existence to photosynthesis. Variation in rate of consumptive and diffusion loss could possibly mask intensity of the photosynthetic process as determined by oxygen measurement. Yet, in general, it appears safe to assume that highest rate produced the greatest oxygen concentration most of the time. Photosynthesis and decomposition-respiration apparently reached their peaks at the same times of the year; maximum oxygen production in each cell, except No. 6, was probably represented by its highest average monthly value. Higher O_2 concentrations were usually associated with high pH values.

Except for ebbs in diurnal "pulses," oxygen was maintained in effluents until ice cover appeared in the winter of 1957–58. Sulfide odors endured for several days following breakup, but were not noted at other times. Cells 1 and 6 never lacked oxygen for as long as 24 hr; other units lost O_2 for one day in December, and for a prolonged period in February and March. Oxygenless conditions persisted for as long as 35 days, but not for the duration of any calendar month.

Certain chemical features associated with development of and recovery from the oxygenless condition induced by ice cover in Cells 3, 4, and 5 are given in Table VII, which presents a day-by-day picture. Entries in this table clearly demonstrate the dependence of oxygen on photosynthesis in these stabilization ponds. In Cell 3, reappearance of oxygen was accompanied by elevations in pH and reductions in HCO_3 alkalinity that became more marked and led to development of CO_3 alkalinity as oxygen concentration increased over the period March 11 to 21. In Cell 4, return of oxygen was delayed until March 25, but its subsequent buildup involved increases in pH and declines in alkalinity that later reversed themselves as O_2 decreased. In Cell 5, oxygen recovery and pH and alkalinity alterations were slower but showed the same relationships.

Alkalinity and pH variation also accompanied changes in oxygen concentration that occurred just before its exhaustion in each of Cells 3, 4, and 5 in February. At that time, oxygen concentration remained far below the saturation level, but pH and alkalinity changes clearly indicated that quantities present owed their origin to photosynthesis. Under ice cover, no absorption from the air was to be expected; however, after ice melted, return of measurable oxygen, and its later variation, were associated with pH and alkalinity changes characteristic of photosynthesis. Absorption from the atmosphere apparently plays a very minor role in supplying oxygen requirements.

Oxygen production varied in different cells, as indicated in Table V and Figure 4, but seasons of highest average values were generally the same for all units except Cell 6, which began an increase in oxygen production in December after other units declined.

Organic Phosphorus

No particular relationship of organic phosphorus to loading can be claimed. Concentration varied from 0.4 to 5.3 mg/l. No pronounced seasonal differences were noted. A slight elevation was measured in Cells 3 and 4 in January. Organic P ranged noticeably below PO_4 in all cells (Table V).

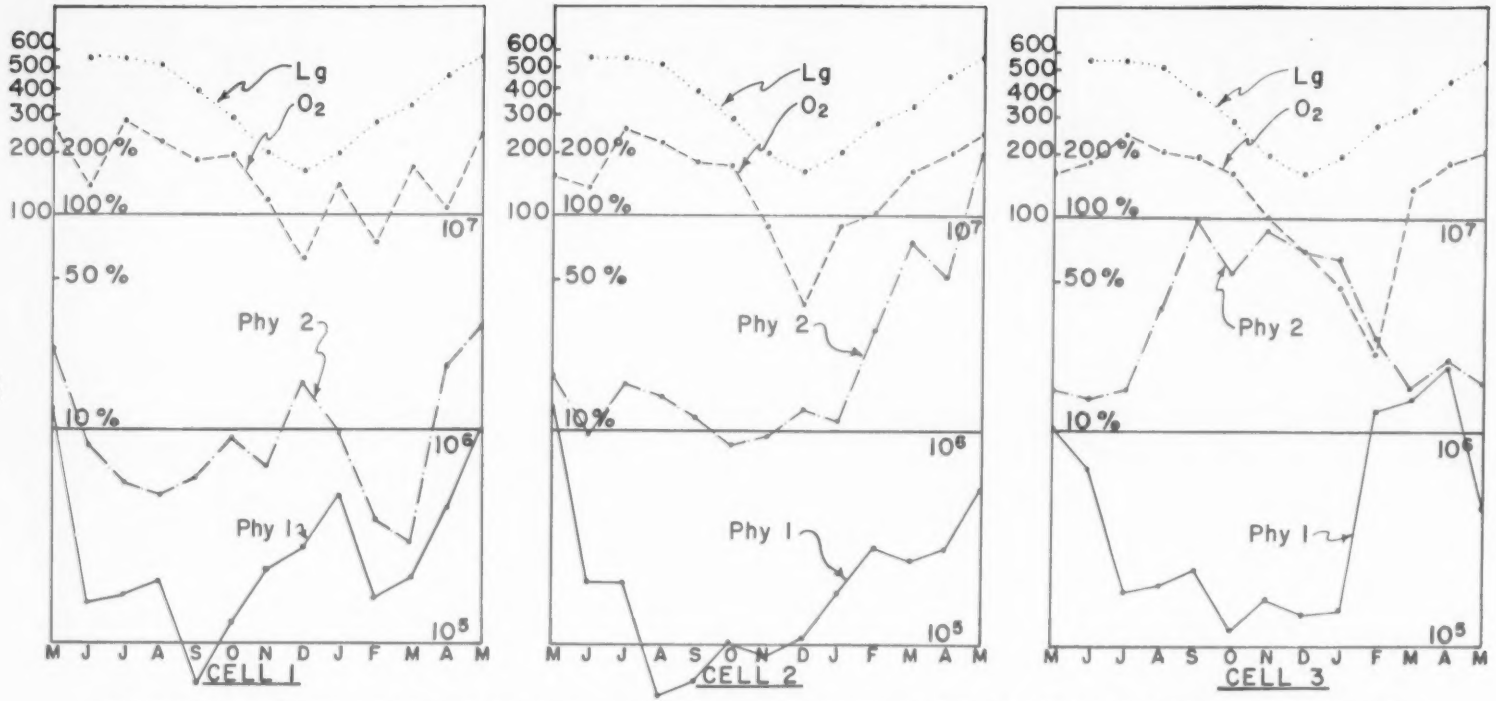

FIGURE 4.—Relationships of solar radiation, oxygen production, and phytoplankton in Cells 1–6. Values are averages per listed months beginning May 1957. Lg = langleys per day; O_2 = oxygen; Phy 1 = number of phytoplankters per ml; Phy 2 = C units per ml. C units may be converted to ppm/volume by multiplying by 0.001768.

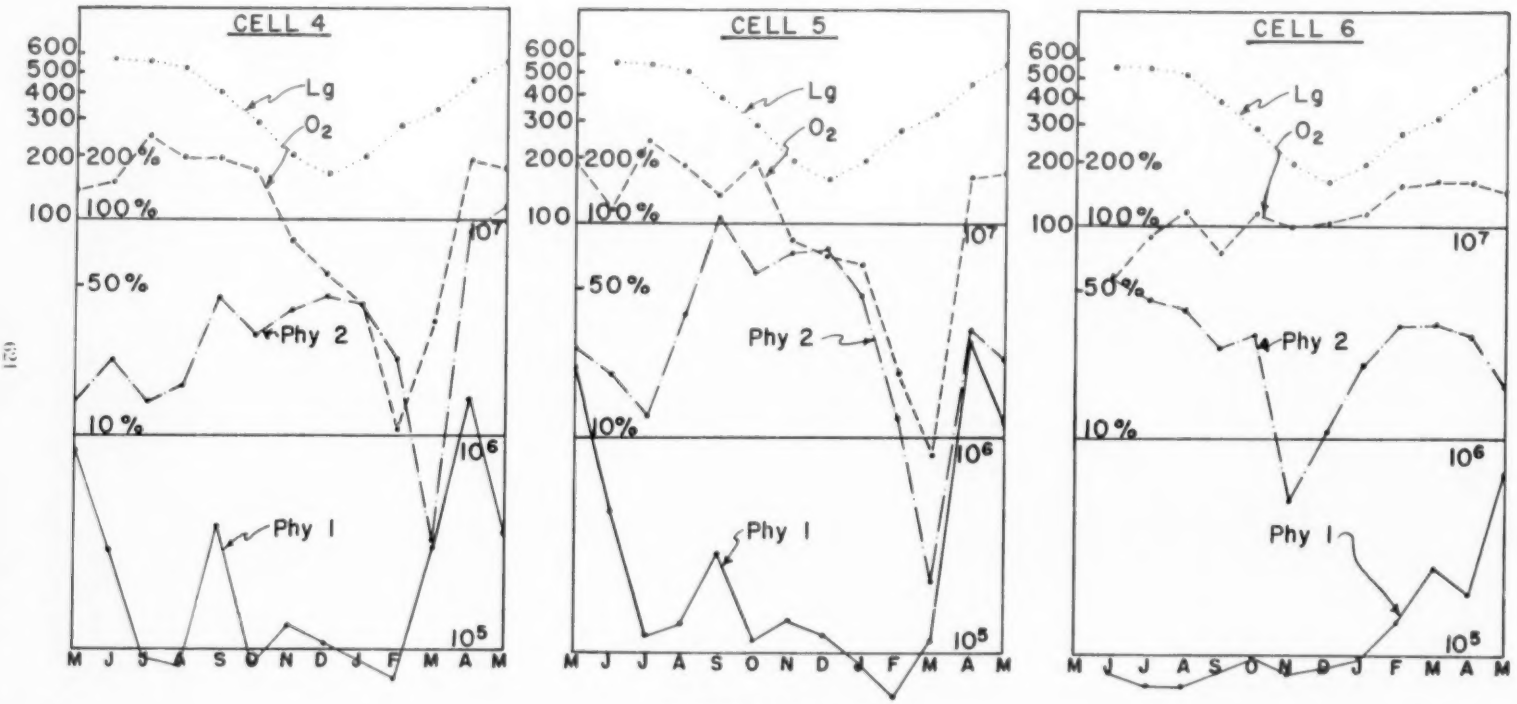

FIGURE 4.—*Continued.*

Phosphate (PO_4)

Although with two to three times the concentration of organic P (range 3.8 to 14.7 mg/l), phosphate showed about the same degree of uniformity over the seasons. Definite elevations occurred in Cells 3, 4, and 5 over the January to March period, and Cell 2 had a barely discernible rise in February. Utilization of phosphorus compounds is discussed in the section on efficiency.

Organic Nitrogen

Highest concentrations (up to 13.5 mg/l) occurred in units with loadings at and in excess of 60 lb BOD/day/acre. Cell 3 experienced a sharp increase in November, and concentration remained at a high level as long as O_2 was below saturation. Decline began again in March. Cells 4 and 5 had increases in February and March, and declines in April, followed by sharp increases in May (Table V). Cells with lighter loads showed rather insignificant fluctuation after June 1957.

Ammonia Nitrogen

Ammonia nitrogen closely followed the course set by organic nitrogen across the seasons in all cells except No. 3, in which it did not increase until January. Its concentration was usually at or very near the average value shown by organic N each month. Its average concentration was also highest in Cells 3, 4, and 5.

Nitrate Nitrogen

Nitrate concentration was always quite low in the raw sewage and it never increased significantly in the

TABLE VIIa.—Development of and Recovery from Oxygenless State Imposed by Ice Cover, Cell 3

Date 1958	pH	CO_2 Alk. (mg/l)	HCO_3 Alk. (mg/l)	O_2 (mg/l)	BOD (mg/l)	Temp. (°C)	Ice Cover	Coliform (MPN)	Phyto-plankton (ppm/ vol.)
2/14	7.5	0.0	243	3.6	—	2.0	Present	—	4,959
2/17	7.7	0.0	228	4.4	—	2.0	Present	—	—
2/18	7.5	0.0	233	2.6	—	2.0	Present	—	—
2/19	—	—	—	0.0	—	2.0	Present	—	—
2/20	—	—	—	0.0	—	2.0	Present	—	—
2/21	—	—	—	0.0	—	2.0	Present	—	—
2/22	—	—	—	0.0	—	2.0	Present	—	—
2/24	—	—	—	0.0	—	6.0	Thawing	—	—
2/25	—	—	—	0.0	—	8.0	Thawing	—	—
2/26	—	—	—	0.0	—	6.5	Absent	—	—
2/27	—	—	—	0.0	—	4.5	Absent	—	—
2/28	—	—	—	0.0	—	5.0	Absent	—	—
3/3	—	—	—	0.0	—	5.0	Absent	—	—
3/4	—	—	—	0.0	—	5.0	Absent	—	—
3/5	—	—	—	0.0	60	5.0	Absent	93,000	504
3/6	—	—	—	0.0	—	5.0	Absent	—	—
3/7	7.3	0.0	232	0.0	—	4.5	Absent	—	—
3/10	7.3	0.0	235	Tr.	—	5.0	Absent	—	—
3/11	7.5	0.0	212	8.8	—	5.0	Absent	—	—
3/12	7.9	0.0	199	14.6	—	5.0	Absent	—	—
3/13	8.0	0.0	195	15.8	—	5.0	Absent	—	—
3/14	8.1	4.0	188	17.8	—	5.0	Absent	—	—
3/17	8.2	8.0	184	19.2	—	5.0	Absent	—	—
3/18	8.4	18.0	173	22.8	—	5.5	Absent	—	—
3/19	8.8	38.0	149	26.4	—	5.5	Absent	—	—
3/20	9.0	58.0	131	30.2	39	5.5	Absent	34,000	—
3/21	9.3	62.0	129	34.1	—	6.0	Absent	—	—
3/26	—	—	—	—	—	—	—	—	5,094

TABLE VIIb.—Development of and Recovery from Oxygenless State Imposed by Ice Cover, Cell 4

Date 1958	pH	CO_3 Alk. (mg/l)	HCO_3 Alk. (mg/l)	O_2 (mg/l)	BOD (mg/l)	Temp. (°C)	Ice Cover	Coliform (MPN)	Phyto-plankton (ppm/ vol.)
2/6	7.3	0.0	242	0.4	—	2.0	Present	—	5,510
2/7	7.5	0.0	240	2.0	—	2.0	Present	—	—
2/10	7.8	0.0	233	4.0	—	2.0	Present	—	—
2/11	7.7	0.0	241	3.0	65	2.5	Present	—	2,359
2/12	7.7	0.0	245	3.0	—	2.0	Present	—	—
2/13	7.4	0.0	247	2.0	—	2.0	Present	—	—
2/14	7.2	0.0	246	1.0	—	2.0	Present	—	—
2/17	7.4	0.0	243	3.0	—	2.0	Present	—	—
2/18	7.3	0.0	248	0.0	—	2.0	Present	—	—
2/19	—	—	—	0.0	—	2.5	Present	—	—
2/20	—	—	—	0.0	—	2.5	Present	—	—
2/21	—	—	—	0.0	—	2.5	Present	—	—
2/22	—	—	—	0.0	—	2.5	Present	—	—
2/24	—	—	—	0.0	—	5.5	Absent	—	—
2/25–3/4	—	—	—	0.0	—	—	Absent	—	—
3/5	—	—	—	0.0	57	5.0	Absent	93,000	8
3/6	—	—	—	0.0	—	5.5	Absent	—	—
3/7	7.3	0.0	238	0.0	—	5.0	Absent	—	—
3/10	7.3	0.0	238	0.0	—	4.5	Absent	—	—
3/11	7.3	0.0	224	0.0	—	4.5	Absent	—	—
3/12	7.4	0.0	210	0.0	—	5.0	Absent	—	—
3/13–24	7.3–7.4	0.0	210–226	0.0	65 (3/20)	5–6	Absent	93,000 (3/20)	—
3/25	7.4	0.0	223	0.5	—	—	Absent	—	—
3/26	7.9	0.0	215	12.0	—	8.0	Absent	—	1,119
3/27	8.3	12.0	204	15.0	—	9.0	Absent	—	—
3/28	8.7	48.0	169	25.0	—	11.5	Absent	—	—
3/29	8.5	22.0	197	17.0	55	10.0	Absent	93,000	—
3/31	8.8	34.0	185	17.0	—	10.0	Absent	—	—

lagoons; in fact, it disappeared from lagoon effluents for months at a time (Tables IV and V). Algae readily use nitrogen in the ammonia state, and apparently limit nitrification activities to that phase. During many months, they apparently also exhausted the sparse amounts of nitrate entering in raw sewage.

Nitrite was present in raw sewage only during May 1957, and was never found in lagoon effluents. Its absence emphasizes lack of nitrification beyond the ammonia stage.

Chloride

Records on chloride content cover only part of the period reported herein, and most cells exhibited but minor variation. Raw sewage showed a noticeable increase in November that was not matched in any lagoon. Higher than usual levels characterized raw sewage and Cells 2, 3, 4, and 5 in February.

Detergent (ABS)

The analysis for detergent (ABS) was discontinued in December 1957.

Biological Features

Coliform-Type Bacteria

MPN's of coliform bacteria reached their highest levels in cells with heavier loadings and shorter retention times (Table V). However, numbers of these organisms were not consistently greater in these cells (3, 4, and 5), and in them dropped to and remained for some time in summer and fall at ranges then displayed by effluents from units with lighter loadings and greater retention times. Highest monthly aver-

TABLE VIIc.—Development of and Recovery from Oxygenless State Imposed by Ice Cover, Cell 5

Date 1958	pH	CO_2 Alk. (mg/l)	HCO_3 Alk. (mg/l)	O_2 (mg/l)	BOD (mg/l)	Temp. (°C)	Ice Cover	Coliform (MPN)	Phyto-plankton (ppm/ vol.)
2/6	7.5	0.0	234	2.0	—	2.0	Present	—	3,641
2/7	7.6	0.0	232	4.0	—	2.0	Present	—	—
2/10	7.9	0.0	229	6.0	—	2.0	Present	—	—
2/11	7.8	0.0	234	6.0	77	2.0	Present	—	641
2/12	7.8	0.0	232	6.0	—	2.0	Present	—	—
2/13	7.6	0.0	243	5.0	—	2.5	Present	—	—
2/14	7.4	0.0	245	3.0	—	2.0	Present	—	—
2/17	7.6	0.0	239	4.0	—	2.0	Present	—	—
2/18	7.4	0.0	242	2.0	—	2.0	Present	—	—
2/19–22	—	—	—	0.0	—	2.0	Present	—	—
2/24–3/4	—	—	—	0.0	—	5.0–6.8	Absent (2/24)	—	—
3/5	—	—	—	0.0	65	5.0	Absent	240,000	61
3/6	—	—	—	0.0	—	5.0	Absent	—	—
3/7–19	7.3–7.4	0.0	224–240	0.0	—	4.5–5.5	Absent	—	—
3/20	7.3	0.0	243	0.0	74	5.5	Absent	1,100,000	—
3/21–25	7.3	0.0	238–246	0.0	—	6.0	Absent	—	—
3/26	7.5	0.0	241	0.3	—	9.0	Absent	—	633
3/27	7.5	0.0	242	2.0	—	9.0	Absent	—	—
3/28	7.5	0.0	244	4.0	—	12.0	Absent	—	—
3/29	7.5	0.0	235	6.0	59	10.0	Absent	93,000	—
3/31	7.6	0.0	231	8.0	—	10.0	Absent	—	—
4/1	7.6	0.0	228	5.0	—	11.0	Absent	—	—
4/4	7.9	0.0	212	7.0	—	11.0	Absent	—	—
4/7	8.1	4.0	183	10.0	—	11.0	Absent	—	—
4/10	8.7	26.0	152	22.0	—	11.0	Absent	—	5,676

ages occurred in March in Cells 1, 4, and 5; February records are lacking because of equipment failure. Cells 2 and 6 experienced highest coliform concentrations in May 1957, but they also showed an increase in March 1958.

The lack of February records precludes assessment of the effects of short-circuiting, and gives no assurance that representative maximum levels were measured. Detention time probably remained constant in each pond, and conditions in each must be assumed responsible for greater coliform survival in late winter and early spring. Temperature had about the same range from December through February, and if low temperature was chiefly instrumental in greater survival, it seems reasonable to look for elevations in November and December, which did not occur. It is possible that some short-circuiting occurred in Cell 5, because one March sample measured 1,100,000 MPN, but concentration in other cells was rather uniform.

Phytoplankton—Qualitative Aspects

Nineteen genera of photosynthetic organisms were observed in the plankton of the six ponds. Morphological change that commonly affects a number of organisms when they enter the sewage pond environment (12) made specific identification uncertain or impossible in a number of cases. Most genera were represented by only one species. The following indicates number of species for each genus and gives specific names where identification was considered valid:

Green Algae

Volvocales

Chlamydomonas spp. (3)

Chlorogonium elongatum Dangeard

Pascheriella tetras Korshikov
Pandorina morum Bory
Carteria sp.

Chlorococcales

Chlorella vulgaris Beyerinck
Golenkinia radiata Chodat
Micractinium pusillum Fresenius
Ankistrodesmus falcatus (Corda) Ralfs
Scenedesmus dimorphus (Türp.) Kütz. (most common *Scenedesmus*)
Scenedesmus sp.
Actinastrum hantzschii Lagerheim
Coelastrum cambricum Arch.
Oocystis sp.
Tetraedron sp.

Euglenophyta

Euglena proxima Dangeard
Euglena proxima var. *amphoraeformis* Szabados
Euglena acutissima Lemmerman
Phacus sp.

Diatoms

Nitzschia sp.

Blue-Green Algae

Oscillatoria sp.
Anabaena flos-aquea (Lyngb.) Brébisson

Seasonal occurrence of the various genera in individual ponds (Table VIII) over the period January 1957 to May 1958 shows a variety of reactions that suggest the following degrees of adaptability:

1. Inhabiting all lagoons at all seasons. Not precluded by rate of loading within these ranges, nor by climatological conditions, nor by any combination of load and weather conditions: clearly exhibited by *Euglena* (largely *E. proxima* and *E. proxima amphoraeformis*).

2. Great tolerance for or well-adapted to lagoon conditions, but less steadfast in appearance, and with some tendency to avoid heavier loadings when solar radiation declines and/or ice cover forms: *Chlamydomonas, Micractinium, Ankistrodesmus, Scenedesmus, Chlorella, Chlorogonium.*

3. Well-adapted to lagoon life under certain conditions not rigidly determined by loading, but sporadic in occurrence: *Oscillatoria.*

4. Favors medium loadings: *Nitzschia.*

5. Favors definite seasons: *Pascheriella, Pandorina, Golenkinia, Actinastrum.*

6. Sporadic and unassociated with obvious features: *Coelastrum, Oocystis, Tetraedron, Carteria, Anabaena.*

7. Seasonal preference for light loadings: *Phacus.*

Degree of adaptability and most influential organisms are perhaps better illustrated by the frequency with which they attained dominance or rank in the 3 to 5 most numerous groups (Table IX). *Chlamydomonas* and *Euglena* colonized the ponds, and maintained a dominant position, with *Pascheriella*, until April 1957, when *Chlorella* and *Micractinium* appeared. In May, *Chlamydomonas* and *Euglena* were greatly outnumbered, but they continued in residence. *Euglena* was never eliminated from the three dominant positions in all cells during any month, and this group frequently regained and maintained dominance over long periods. *Chlamydomonas* regained dominance or near dominance in July 1957, but gradually declined in importance thereafter, ascending to dominance only once (Cell 2, Dec. 1957).

Although constantly contending with *Euglena*'s marked adaptability to this environment, members of the Chlorococcales, *Chlorella, Micractinium, Scenedesmus*, etc., dominated the summer of 1957, and appeared well on the way to regain this position in May 1958. Greatest numbers of organisms were produced by their proliferation; highest rate of growth and densest

TABLE VIII.—Seasonal Occurrence of Phytoplankters in Individual Ponds
(Numbers Under Months Indicate Cells in Which the Designated Organism Occurred)

Phytoplankter	1957 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
Green Algae									
Volvocales									
Chlamydomonas	1	1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5, 6	—	1, 2, 3, 4, 5	1, 2, 3, 4, 6	1, 2, 3, 4, 6	2, 3, 6	—
Chlorogonium	—	—	—	3, 6	1, 2	—	2, 3, 4, 5, 6	1, 2, 4	1, 2
Pascheriella	—	1, 2, 3, 4, 5	1, 2, 3, 4, 5, 6	—	—	—	—	—	—
Pandorina	—	—	—	—	—	6	1, 2, 3, 4, 5	1, 2, 4, 5	1, 6
Carteria	—	—	—	—	—	—	—	—	—
Chlorococcales									
Chlorella	1	—	6	3, 5, 6	2, 3, 4, 5	4, 5, 6	1, 4	1, 2, 3, 4, 5	1, 2, 3, 4, 5
Golenkinia	—	—	1, 2, 4, 5	—	—	3	—	—	—
Micractinium	1	—	1, 6	3, 5, 6	1, 2, 3, 4, 5	1, 3, 4, 5, 6	1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5, 6
Ankistrodesmus	1, 5	—	6	3, 5, 6	1	6	4, 6	2, 3, 4, 5, 6	3, 4, 5, 6
Scenedesmus	1	—	—	3	1, 2, 4	1, 2, 3, 4, 6	1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5, 6
Actinastrum	—	—	—	—	1	1, 5	1, 4, 5, 6	4, 5, 6	4, 5, 6
Coelastrum	—	—	—	—	—	—	4	—	—
Oocystis	—	—	6	4	4	2	2	2	—
Tetraedron	—	—	—	3	—	—	—	—	—
Euglenophyta									
Euglena	1, 5	1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5, 6	3, 6	1, 2, 3, 4, 5	1, 2, 3, 4, 5	1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5, 6
Phacus	—	—	—	—	—	—	—	4, 6	1, 2, 6
Diatoms									
Nitzschia	—	—	—	—	1, 2, 3, 5	3	3	3	—
Blue-Green Algae									
Oscillatoria	5	—	—	3, 5	5	4, 6	1, 2, 4, 5, 6	1, 2, 4, 5, 6	1, 6
Anabaena	—	—	—	—	—	—	—	—	—

Phytoplankter	1957 Oct.	Nov.	Dec.	1958 Jan.	Feb.	Mar.	Apr.	May
Green Algae								
Volvocales								
Chlamydomonas	1, 2, 6	1, 2, 3, 6	1, 2, 3, 6	1, 2, 4, 6	1, 4, 5, 6	—	1, 2	1, 3, 4, 5, 6
Chlorogonium	1, 2, 4, 5, 6	1, 2, 3, 4, 5, 6	2	—	4, 6	2, 5	1, 2, 4	1, 2, 3, 4, 6
Pascheriella	—	—	—	—	—	—	—	—
Pandorina	6	—	—	—	—	—	—	—
Carteria	—	1, 4	4	—	—	—	—	—
Chlorococcales								
Chlorella	1, 2, 3, 4, 5, 6	1, 2, 6	1, 2, 3, 5	1, 2, 3	1, 2, 3	2, 3, 4, 5	1, 2, 3, 4, 5	1, 2, 3, 4, 5, 6
Golenkinia	—	—	—	—	—	—	—	—
Micractinium	1, 4, 5, 6	1, 2, 4, 5, 6	1, 2, 5, 6	1, 2, 6	1, 2, 5, 6	1, 2, 3, 4, 5, 6	1, 2, 6	1, 2, 3, 6
Ankistrodesmus	1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5, 6	1, 2, 3, 5, 6	1, 2, 3, 4, 5, 6	1, 2, 4, 5, 6	1, 4, 6	1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5, 6
Scenedesmus	2, 3, 4, 5, 6	1, 2, 3, 4, 5, 6	1, 2, 3, 5, 6	1, 2, 3, 4, 6	1, 2, 4, 5, 6	2, 5	1, 2, 4	1, 3, 4, 6
Actinastrum	4, 5	1, 4, 5, 6	—	—	4, 6	—	—	4
Coelastrum	4	2, 3	2	—	—	—	4	—
Oocystis	5	2	—	—	—	—	2	—
Tetraedron	—	1	1	—	—	—	—	—
Euglenophyta								
Euglena	1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5, 6	2, 3, 4, 5, 6	1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5, 6
Phacus	6	1, 2	—	—	—	—	—	—
Diatoms								
Nitzschia	3	3	3	—	—	—	—	3
Blue-Green Algae								
Oscillatoria	4, 5, 6	1, 2, 4, 5, 6	5	—	4, 6	4, 5	—	1, 4, 6
Anabaena	—	—	—	—	6	—	—	—

TABLE IX.—Most Numerous (Dominant) Organisms in Descending Order for Each Pond Each Month

Month	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
1957 Jan.	*Chlorella* *Micractinium* *Chlamydomonas*	No Sample	No Sample	No Sample	*Euglena* *Ankistrodesmus* *Oscillatoria*	No Sample
Feb.	*Chlamydomonas* *Euglena*	*Chlamydomonas* *Euglena* *Pascheriella*	*Chlamydomonas* *Euglena* *Pascheriella*	*Chlamydomonas* *Euglena* *Pascheriella*	*Chlamydomonas* *Euglena* *Pascheriella*	*Chlamydomonas* *Euglena*
Mar.	*Chlamydomonas* *Euglena* Replaced by *Golenkinia* *Micractinium*	*Chlamydomonas* *Euglena* *Pascheriella* (*Golenkinia* 3/28)	*Chlamydomonas* *Euglena* *Pascheriella*	*Chlamydomonas* *Euglena* *Pascheriella* Replaced by *Golenkinia* 3/20	*Euglena* *Chlamydomonas* *Pascheriella* Replaced by *Golenkinia* 3/20	*Pascheriella* *Chlorella* *Euglena* *Micractinium*
Apr.	No Sample	No Sample	*Euglena* *Chlorella* *Micractinium*	No Sample	*Chlorella* *Micractinium* *Oscillatoria*	*Chlorella* *Micractinium* *Euglena*
May	*Micractinium* *Chlorella* *Chlamydomonas* *Chlorogonium*	*Micractinium* *Chlamydomonas* *Chlorella* (dom. 5/13) *Scenedesmus*	*Chlorella* *Micractinium* *Chlamydomonas* *Euglena*	*Chlorella* *Micractinium* *Chlamydomonas*	*Chlorella* *Micractinium* *Chlamydomonas*	No Sample
June	*Micractinium* Replaced by *Chlamydomonas* *Oocystis*	*Scenedesmus* *Chlamydomonas* *Oocystis*	*Micractinium* *Chlorella* *Chlamydomonas* *Golenkinia* (dom. 6/27)	*Chlorella* *Chlamydomonas* *Micractinium*	*Chlorella* *Chlamydomonas* *Micractinium* *Euglena*	*Oscillatoria* *Chlorella* *Chlamydomonas* *Micractinium*
July	*Chlorella* *Chlamydomonas* (dom. 7/3)	*Scenedesmus* *Chlamydomonas* (dom. 7/30) *Micractinium* (dom. 7/26) *Oscillatoria*	*Micractinium* *Chlamydomonas* *Euglena* *Pandorina* (dom. 7/30)	*Chlamydomonas* *Micractinium* *Euglena* *Oscillatoria* *Chlorogonium*	*Chlamydomonas* *Micractinium* *Euglena* *Scenedesmus* (dom. 7/30)	*Oscillatoria* *Chlamydomonas* *Scenedesmus*
Aug.	*Chlorella* *Oocystis* *Scenedesmus*	*Scenedesmus* (dom. 8/21, 8/27) *Chlorella* (dom. 8/2, 8/15) *Micractinium* *Euglena*	*Micractinium* *Euglena* (dom. 8/27) *Chlorella*	*Chlorogonium* *Actinastrum* *Euglena* *Micractinium* *Chlorella*	*Euglena* *Scenedesmus* (dom. 8/2) *Chlorella* *Micractinium*	*Oscillatoria* *Scenedesmus* *Micractinium* *Chlamydomonas* *Euglena*
Sept.	*Chlorella* *Scenedesmus* *Micractinium* *Euglena*	*Scenedesmus* *Phacus* *Euglena* *Chlorella*	*Euglena* *Micractinium* *Ankistrodesmus* *Chlorella*	*Ankistrodesmus* *Euglena* *Chlorella* *Scenedesmus*	*Euglena* *Ankistrodesmus* *Chlorella*	*Euglena* *Phacus* *Micractinium* *Oscillatoria*
Oct.	*Scenedesmus* *Chlorella* *Euglena*	*Chlorella* *Scenedesmus* *Euglena* *Chlamydomonas*	*Euglena* *Chlorella* *Scenedesmus* *Ankistrodesmus*	*Euglena* *Ankistrodesmus* *Chlorogonium*	*Euglena* *Ankistrodesmus* *Micractinium*	*Euglena* *Micractinium* *Phacus* *Chlorella*
Nov.	*Chlorella* *Carteria* *Micractinium*	*Chlorella* *Carteria* *Scenedesmus*	*Euglena* *Chlamydomonas* *Ankistrodesmus* *Oscillatoria*	*Euglena* *Ankistrodesmus* *Chlorogonium* *Carteria*	*Euglena* *Ankistrodesmus* *Chlorogonium*	*Micractinium* *Chlamydomonas* *Euglena*
Dec.	*Micractinium* *Chlamydomonas* *Chlorella*	*Chlamydomonas* *Chlorella* *Euglena*	*Euglena* *Chlorella* *Chlamydomonas* *Scenedesmus*	*Euglena* *Carteria*	*Euglena* *Micractinium* *Scenedesmus*	*Micractinium* *Euglena* *Chlamydomonas*
1958 Jan.	*Chlorella* *Micractinium* *Euglena*	*Chlorella* *Euglena* *Micractinium*	*Euglena* *Chlorella* *Scenedesmus*	*Euglena* *Chlamydomonas* *Ankistrodesmus*	*Euglena* *Ankistrodesmus*	*Micractinium* *Euglena* *Ankistrodesmus*
Feb.	*Chlorella* *Micractinium* *Euglena*	*Chlorella* *Euglena* *Micractinium*	*Chlorella* *Euglena*	*Euglena* *Ankistrodesmus* *Scenedesmus*	*Euglena* *Ankistrodesmus* *Scenedesmus*	*Chlorogonium* *Euglena* *Micractinium* *Ankistrodesmus*
Mar.	*Micractinium* *Ankistrodesmus* *Oocystis*	*Euglena* *Micractinium* *Chlorella*	*Chlorella* *Euglena* *Micractinium*	*Euglena* *Chlorella* *Oscillatoria*	*Euglena* *Chlorella* *Chlorogonium* *Oscillatoria*	*Euglena* *Micractinium* *Ankistrodesmus*
Apr.	*Chlorella* *Euglena* *Micractinium*	*Euglena* *Micractinium* *Chlamydomonas* *Chlorella*	*Chlorella* *Euglena* *Ankistrodesmus*	*Chlorella* *Euglena* *Ankistrodesmus* *Scenedesmus*	*Chlorella* *Euglena* *Ankistrodesmus*	*Euglena* *Micractinium* *Ankistrodesmus*
May	*Chlorella* *Micractinium* *Euglena* *Ankistrodesmus*	*Euglena* *Chlorella* *Micractinium*	*Chlorella* *Micractinium* *Scenedesmus*	*Euglena* *Chlorella* *Ankistrodesmus*	*Chlorella* *Micractinium* *Ankistrodesmus* *Euglena*	*Chlorella* *Micractinium* *Ankistrodesmus* *Euglena*

numerical concentration were exhibited by *Chlorella*. Chlorococcales appeared to be most favored by warmest weather, and in cells with lightest loading (except Cell 6) during the winter of 1957–58. A move toward general dominance by *Chlorella* was evident in April 1958. Rank in Table IX depends on predominance over a period of time and not on total numbers produced during the month. In most instances, the dominant organism ranked No. 1 all month, or No. 1 most of the month and No. 2 at other times. Changes in dominance or overwhelming development of another organism on one date are indicated.

Phytoplankton—Quantitative Aspects

Objectives of the first operational phase made plankton analysis of pond effluents desirable, and personnel limitations practically restricted it to these samples. Effluents are discharged from or very near the surface, a zone summer phytoplankters usually avoid to escape unfavorable or lethal light intensities. Maximum densities during warmer months were in all likelihood not represented in the effluents; therefore, an exact comparison of plankton production in various cells is not attempted. Densities expressed as number of organisms per milliliter do not necessarily reflect differences in total mass of phytoplankton, because size varies over a wide range; valid comparisons are possible only when the same group or groups of organisms are present. However, reasonably close estimates on a volumetric basis may be arrived at by determining average dimensions of each group. Average values in ppm by volume are shown in Table X.

TABLE X.—Quantitative Accounting of Phytoplankton

Phytoplankter	(ppm/vol.)
Chlamydomonas	
Large	0.0154
Intermediate	0.0046
Elongate	0.0047
Carteria	0.0042
Pascheriella	0.0023
Chlorogonium	0.02
Pandorina	0.157
Chlorella	0.001768
Ankistrodesmus	0.0012
Micractinium	0.0028*
Golenkinia	0.0024
Actinastrum	0.002
Scenedesmus dimorphus	0.007
Coelastrum	0.013
Tetraedron	0.009
Oocystis	0.008
Euglena proxima	0.104
Euglena prox. var. *amphoraeformis*	0.038
Euglena acutissima	0.2
Phacus	0.046
Nitzschia	0.002
Oscillatoria	0.2

* 4-cell unit.

Average phytoplankton densities in ppm by volume and number of organisms per ml are given in Table XI. Volume figures indicate that production increased with load up to 60 lb BOD/day/acre and then leveled off. Cell 6 was intermediate between Cells 1 and 2 on a monthly average, but had a greater 13-month mean than Cell 2. Cell 4 fell below Cell 3, but Cells 3 and 5 were about equal in productivity. The various units exhibited individual tendencies; it is probable that monthly maximum densities were missed in some and caught in others. Individual variation attributable to other factors in all probability modified to some degree the influences of varied loading rates.

The three most heavily loaded cells had quite similar seasonal variations in volume of phytoplankton (Cell 4 was in a lower range), and in them seasonal fluctuation in numbers of individuals was fairly alike. However, they each showed markedly different trends between numbers and volume (Figure 4); and, over much of the period covered by this report, higher volumes were associated with lower numbers of organisms (that is, greater masses of plankton were produced by larger organisms most of the time). Cell 3 values in Figure 4 and Table XI show that wide divergence in trends of

TABLE XI.—Average Phytoplankton Density in Number of Organisms Per ml and ppm by Volume

Month	Cell 1		Cell 2		Cell 3		Cell 4		Cell 5		Cell 6	
	(No.)	(ppm/vol.)	(No.)	(ppm/vol.)	(No.)	(ppm/vol.)	(No.)	(ppm/vol.)	(No.)	(ppm/vol.)	(No.)	(ppm/vol.)
1957												
May	1,294,926	4,186	1,216,264	3,076	1,087,226	2,824	838,716	2,415	2,156,804	4,506	—	—
June	155,992	1,485	196,261	1,689	686,572	2,541	270,248	3,902	442,983	3,373	65,432	9,459
July	169,822	1,011	192,097	2,916	175,380	2,719	79,973	2,456	115,279	2,134	47,501	7,934
Aug.	196,419	871	65,965	2,525	190,928	6,652	62,147	2,968	132,349	6,302	44,966	7,236
Sept.	70,485	1,052	71,595	2,005	227,365	19,163	361,398	7,631	283,053	19,268	64,751	4,698
Oct.	128,390	1,646	102,114	1,468	119,510	10,026	67,719	4,995	111,370	10,315	91,760	5,383
Nov.	220,881	1,141	90,345	1,629	164,981	15,755	125,490	6,620	137,680	12,990	63,197	911
Dec.	279,350	2,918	108,040	2,189	140,384	12,692	103,220	7,708	128,991	13,138	77,519	1,825
1958												
Jan.	490,468	1,668	172,175	2,114	146,100	11,436	72,326	6,947	79,698	8,167	91,590	4,041
Feb.	102,437	658	285,954	5,386	1,296,283	4,803	41,202	3,935	24,877	2,141	142,667	6,018
Mar.	198,091	511	247,790	13,265	1,411,303	2,799	274,821	563	113,356	347	255,955	6,280
Apr.	423,870	3,569	279,740	8,948	2,067,165	3,870	1,491,177	15,459	2,800,945	5,676	190,280	5,558
May	967,612	5,449	550,723	34,773	429,432	2,967	347,427	20,314	1,147,360	4,097	763,605	3,099
13-Mo avg	392,732	2,020	310,961	5,586	526,129	7,367	309,274	6,005	563,449	7,111	140,632	5,593
Monthly avg	366,057	2,013	275,313	6,307	626,356	7,557	318,150	6,609	594,980	7,112	158,269	5,201

numbers and volume reflected changes in composition, and that when qualitatively similar populations persisted, numbers and volume were more directly related.

Cells 4 and 5 exhibited seasonal volume and number trends that were similar to those noted in Cell 3, but they declined to markedly lower levels in February and March. In Cell 1 (Figure 4), some group of the Chlorococcales was dominant from May 1957 to May 1958. Decline in numbers in summer induced reduction in volume and, with minor short-range differences, volume and number seemed directly related. Volume, however, never reached higher levels displayed by Cells 3, 4, and 5. A member of the Chlorococcales or *Chlamydomonas* was predominant in Cell 2 until March 1958, when *Euglena* assumed dominance and maintained control through May. Maximum volume noted in any unit occurred here in May 1958. Cell 6 possessed the volume-augmenting effect of *Oscillatoria* in summer of 1957, when volume and numbers were indirectly related. Volume decreased when *Euglena* became the most numerous organism and declined sharply when *Micractinium* gained numerical superiority. With the exception of Cell 2 in May 1958, lighter loadings did not produce volume levels equal to those exhibited by cells with loadings at or above 60 lb BOD/day/acre.

Average oxygen values in terms of per cent saturation are shown with average density and volume figures for plankton in Figure 4. Oxygen has seasonal variation that is related to changes in intensity of sunlight, as described in the following section, and the reader is cautioned not to attempt to relate its variation to plankton volume or density alone. These charts (Figure 4) suggest that maximum O_2 production is more associated with some qualitative feature of phytoplankton, such as kinds of organisms or age of the population, than with mass or density.

Interrelationships

Objectives of this 13-month study period required routine sampling of effluents; available personnel seldom allowed collection and handling of more than one series of samples per day. To check on oxygen pulses and other features subject to diurnal variation, time of sampling was often changed from day to day. Thus, one day's analyses

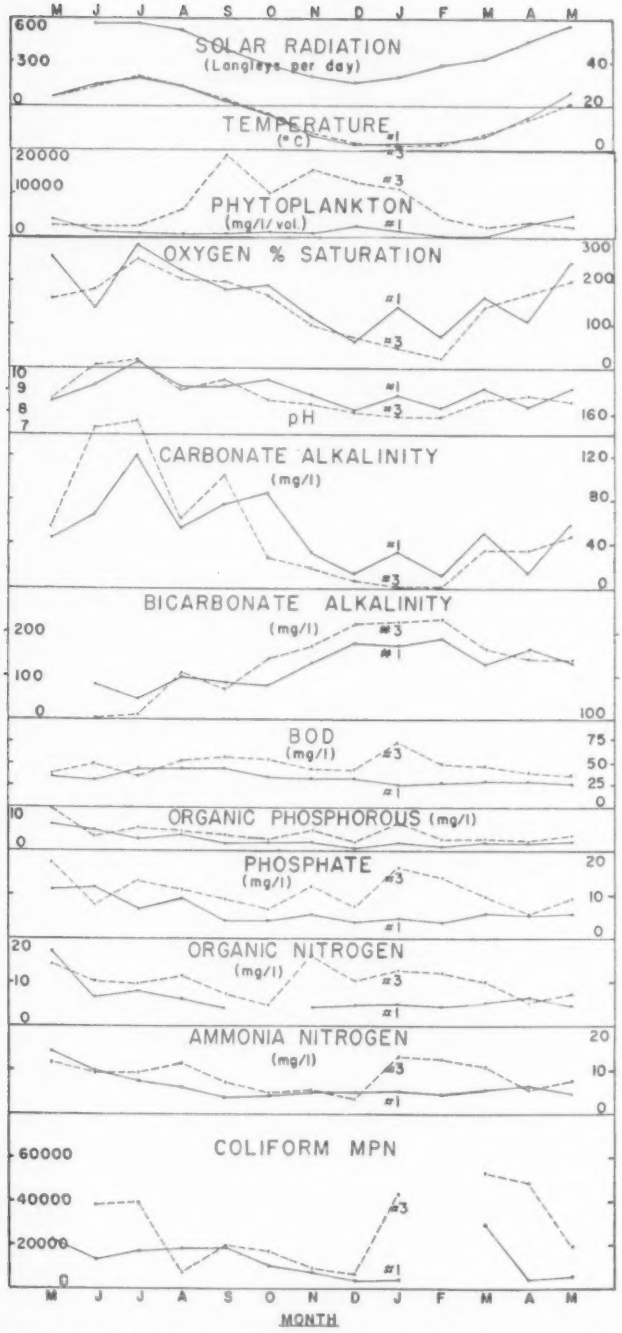

FIGURE 5.—Interrelationships of various analyses as indicated by monthly averages in Cells 1 and 3 and mean solar radiation.

TABLE XII.—Survival of Coliform-Type Bacteria

Loading (lb BOD/day/acre)	Effluent Range (MPN)			Per Cent of Samples Equal to or Greater Than	
	Min Value	Arith. Avg	Max* Value	43,000/100 ml	93,000/100 ml
20	430	14,700	43,000	16	0
40	3,600	24,700	93,000	29.5	7.9
60	430	24,300	93,000	24.5	8.9
80	2,400	34,000	93,000	48	18
100	2,400	40,200	93,000	47	19.2

* Exclusive of short-circuiting.

reflected early morning conditions, another's late afternoon, etc., and no absolute assurance exists that upper limits were ever noted or that lower extremes were included during any month when no zero values occurred. Surface samples are best suited for evaluation of treatment efficiency, but they obscure or leave unsettled certain relationships involving algae and photosynthesis. The following account recognizes these limitations.

As demonstrated by the Kearney, Neb., experimental stabilization pond (3), life processes of algae, particularly photosynthesis, have a powerful influence—almost dictatorial powers—over pond chemistry and biology. Interrelationships of various analyses conducted at Fayette and their kinship to solar radiation are shown in Figure 5 by monthly averages of data from Cells 1 and 3. Other cells varied from these trends, but not sufficiently to discount relationships and interpretations indicated by their study.

Relationships shown in Figure 5 appear to merit little discussion here. Association of phytoplankton mass with solar radiation should be guided by possible errors introduced by migration in and out of surface layers as lethal influences of light fluctuated.

Influences of seasonal variation in photosynthetic rate at Fayette were quite similar to those noted at Kearney, insofar as they affected oxygen, pH, and alkalinity. Changes in chemical indexes of intensity of this process were not as well related to plankton concentration at Fayette, and BOD was noticeably less affected by seasonal change. Fayette units never lost phytoplankton completely and had low concentrations for only brief periods of time, whereas at Kearney plankton algae were absent or at low densities for months during fall, winter, and early spring, when BOD was most concentrated.

Performance

Removal of Coliform-Type Bacteria

Efficiencies varied only in the third and fourth decimal places, and no cell failed to remove 99.99 per cent of these bacteria over any month of record. Level of removal by the entire facility (Table XVII) did not vary markedly from that accomplished by the most lightly loaded unit. Numbers surviving in effluents from Cells 1 to 5 are given in Table XII.

Per Cent BOD Reduction

Efficiencies on a concentration basis for Cells 1, 2, 3, 4, and 5 are given in Table XIII, which rates monthly effluent concentration against individual monthly average raw waste concentrations. Cell 6, which received around 15 lb of raw sewage BOD/day/acre, also had to deal with effluents from the other cells, which could have augmented or decreased the raw sewage load in accord with degree of oxygen saturation. Uncertainty as to its true load has caused its omission from Table XIII, but an estimated load and per cent reduction may be computed by

TABLE XIII.—Per Cent Removal of BOD Average Monthly Effluent Concentration vs. Average Monthly Raw Sewage Concentration

Value	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5
Max	90	89	87	89	87
Min	84	82	72	72	72
Avg	87	86	82	81	82

reference to Tables III, IV, and V. Its effluent is used in Table XVII to show level of treatment accomplished by the entire facility.

Greatest per cent reduction was effected in Cells 1 and 2; variation among Cells 3, 4, and 5 was insufficient to suggest any particular advantage for any rate of loading between 60 and 100 lb BOD/day/acre. If short-circuiting had not developed in the more heavily loaded units, it is doubtful that their efficiencies would have averaged significantly lower than those realized with loadings of 20 to 40 lb BOD/day/acre. It should be remembered that part of effluent oxygen demand was exerted by algae, and actually represented stabilized organic matter that would have been a source of oxygen under normal conditions. Reduction of oxygen-consuming substances must be assumed greater than indicated by the standard BOD test, which considers only the oxygen consumptive and not the productive phase of algal metabolism. Studies that endeavor to arrive at an accurate factor that may be applied to permit subtraction of algal effects are still underway. (Refer to Table V for BOD concentrations in effluents from various cells.)

Reduction of Other Sewage Components

Alkalinity

Reduction of alkalinity is almost exclusively referable to algae, as it normally arises through photosynthetic precipitation of carbonate (see alkalinity section under Chemical Features). Pond concentration was lowered sufficiently to dilute sewage and keep effluent concentrations below those of raw sewage during those months when photosynthesis was reduced or lacking in the more heavily loaded units. Efficiencies in this respect are given in Table XIV. A slight decline in removal accompanied increased loading up to 80 lb BOD/day/acre. Alkalinity removal is most influenced by the intensity of photosynthesis at times of sampling and can vary markedly at different times of the day (Table VI). Concentrations evident during non-photosynthetic seasons may reflect long-term or accumulative effects of photosynthesis, but most reduction is realized in effluent discharged during peak periods of photosynthesis.

TABLE XIV.—Per Cent Removal* of Total Alkalinity

Value	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
Avg	33	31	28	26	26
Min	26	17	19	7	15
Max	42	39	44	48	42

$$* 100 - \left(\frac{\text{Pond mg/l}}{\text{Raw Sewage mg/l}} \times 100 \right)$$

Nitrogen

Nitrogen removal expressed as percentage of raw sewage concentration is

TABLE XV.—Per Cent Reduction* in Concentration of Organic, Ammonia, and Total Nitrogen

Value	Cell 1			Cell 2			Cell 3			Cell 4			Cell 5		
	Org. N	NH_3—N	Total N	Org. N	NH_3—N	Total N	Org. N	NH_3—N	Total N	Org. N	NH_3—N	Total N	Org. N	NH_3—N	Total N
Avg	96	81	93	95	77	92	92	73	89	92	71	89	93	72	89
Min	93	63	88	92	51	85	89	63	82	75	53	81	87	51	80
Max	98	89	97	98	88	96	95	93	94	97	89	96	97	87	96

$$* 100 - \left(\frac{\text{Pond mg/l}}{\text{Raw Sewage mg/l}} \times 100 \right)$$

TABLE XVI.—Per Cent Reduction* in Concentration of Organic Phosphorus, Phosphate (PO_4), and "Total" Phosphorus

Value	Cell 1			Cell 2			Cell 3			Cell 4			Cell 5		
	Org. P	PO_4	Total P	Org. P	PO_4	Total P	Org. P	PO_4	Total P	Org. P	PO_4	Total P	Org. P	PO_4	Total P
Avg	81	80	80	77	75	76	69	66	67	67	67	67	67	67	67
Min	55	61	62	52	56	60	55	35	41	27	31	33	34	38	43
Max	96	90	92	97	87	90	87	81	83	97	85	88	88	83	84

* $100 - \left(\frac{\text{Pond mg/l}}{\text{Raw Sewage mg/l}} \times 100\right)$

given in Table XV. Organic nitrogen exhibited a much more consistent pattern; its removal was generally 8 to 10 per cent greater than that of ammonia nitrogen. Although exact mechanisms are unknown, these differences suggest that organic nitrogen is mainly reduced by bacterial action and that ammonia is chiefly utilized by algae.

Inasmuch as a large share of organic N is converted into ammonia nitrogen, utilization of NH_3–N exceeds the quantities available in raw sewage, and a more exact representation of nitrogen reduction may be secured by computing reduction of the sum of organic and ammonia nitrogen. Degree of purification on this basis (total nitrogen) is also given in Table XV. Because measurement of the two types of nitrogen compounds is not influenced by living organisms contending with an abnormal environment, their combined concentrations may be more accurate indexes of waste treatment efficiency than BOD. They enter into the dynamic life processes, and their generally higher removal rates may indicate a level of purification that is usually hidden by algal influences when BOD is considered.

Phosphorus

Degree of phosphorus utilization is indicated by per cent removals of raw sewage concentrations in Table XVI. Average rate of reduction over the 12-month period was very similar for organic P and PO_4, but they differed markedly during some months. Phosphate levels are augmented by oxidation of organic P, and PO_4 consumption is greater than its indicated relation to PO_4 concentration of the raw waste. Removal of "total" phosphorus is shown in the third column under each cell.

Performance of Total Facility

Final effluent from the system of ponds was discharged from Cell 6, and its concentration of sewage elements in relation to those of raw sewage (per cent reductions) is given in Table XVII. In comparison to Cells 3, 4, and 5, Cell 6 received only a small portion of the raw waste, and because it received effluents from all other cells

TABLE XVII.—Degree of Treatment (Per Cent Reduction of Waste Components) Achieved by the Entire Facility

Value	Alk.	BOD	Org. P	PO_4	Total P	Org. N	NH_3—N	Total N	MPN
Avg	32	89	78	78	80	95	82	93	99.9996
Min	21	86	66	68	68	90	56	84	99.9982
Max	43	96	92	91	98	98	93	97	99.9999

it served in a large measure as a secondary unit in a series operation. When its share of energy was increased following reduced photosynthesis in other units, its oxygen production grew and protected the final effluent from declines that occurred in some other cells. It also maintained a high level of BOD reduction, near peak alkalinity removal, and brought about maximum reduction of coliform-type bacteria at times when their levels had increased in other units. These actions clearly illustrate the advantages of series operation for high effluent quality.

Discussion and Conclusions

Performance and Energy Relationships

Based on quality of final effluent from Cell 6, performance of the entire facility was outstanding. Purification achieved by individual 0.75-acre units was very good on a monthly basis; however, cells with daily BOD loadings of 60 to 100 lb/acre suffered decline of photosynthesis under ice cover and produced sulfide odors at breakup. Effluent from these units was poor in quality on a few dates (Table VII). Cell 5, for example, had a coliform count of 1,100,000 MPN per 100 ml on March 20, 1958. Odors endured for several days after ice melt, but they were never strong enough to reach human habitations. Effluent quality was quickly elevated in Cell 6. Shallow ponds (that is, 5 ft or less), if fairly rich in organic matter, always face the danger of complete oxygen loss under ice cover. It does not appear practicable, or even possible, to have sewage loading low enough to eliminate this hazard.

Relationships of loading and solar radiation to photosynthetic rate, and known factors associated with efficiency of solar energy consumption are developed in the following account.

Solar radiation influences on efficiency, oxygen production, and other features were overshadowed at times by other limiting factors. Cell 6 developed its maximum photosynthetic intensity not in response to a high level of solar radiation, but in reaction to entrance of greater amounts of algal nutrients. Cell 1, in accord with nutrient level change within itself, displayed variations in rate of photosynthesis in winter and spring that were seemingly quite independent of increasing light intensity (Figure 4). In Cell 2, oxygen production and solar radiation were closely related. Cells 3, 4, and 5 were the only units in which light absorption by ice cover noticeably affected photosynthesis.

It is apparent from these observations that solar radiation was but one of several factors exercising control over photosynthesis. When the load was 40 lb BOD/day/acre, or more, light intensity fairly well dictated the level of the photosynthetic process. With lower loadings, light effects were subordinate to those exercised by changes in available algal nutrients. Cell 1's upper level of oxygen production apparently was reached when sewage contributions were augmented by nutrients released from decay of former plankton populations and other growths. Additional energy came to Cell 6 from another source, as described. Raw sewage loads diverted to Cells 2, 3, 4, and 5 seemingly maintained a nutrient supply that would consistently support photosynthesis up to the limitations imposed by available light supply and other physical features. Ponds with higher loadings, however, were unable to maintain a level of photosynthesis sufficient to produce measurable O_2 under ice cover, whereas light filtered through ice and snow was still adequate to support detectable oxygen production with loadings of 20 lb BOD/day/acre or less. Rate of oxygen consumption imposed by heavier loadings (60 lb BOD/day/acre) was too high to be satisfied by reduced production under ice cover.

During open-water seasons, percentage reduction of waste components was about the same at all loadings. Higher loadings applied at Fayette made greater utilization of solar energy possible and were therefore more efficient in open-water seasons than the lighter applications that often failed to use all available light.

Despite variations that occurred in Cell 1, and with the exception of Cell 6, photosynthesis generally varied directly with intensity of solar radiation (Figure 4). The cell loaded at 40 lb BOD/day/acre was less affected by light loss through ice cover than any higher loading and had more direct response to change in light intensity. These observations suggest that this rate of loading is about the maximum amount of raw sewage that can be applied per acre at this latitude with reasonable assurance of a modicum of odor development.

Operation and Loading Considerations

The foregoing details indicate that waste purification is best served by high summer and low winter loadings. A single cell would in most instances require design on the basis of desirable winter loadings; and provision of twin-cell or multiple-cell facilities to allow proper seasonal load adjustment by putting units in and out of service would increase construction costs. A more reasonable and in most cases more economical approach would be provision of a two-cell or multiple-cell, in-series facility. This type would combine the virtues of each desirable loading range, summer and winter, and actually afford greater protection of effluent quality than any reasonable loading applied to a single-cell facility. The primary chamber could receive a load great enough to take full advantage of available solar radiation (for example, 60 lb BOD/day/acre at Fayette, Mo.). Its effluent would introduce a much lower energy load into the second chamber, and additional purification would ensue. When winter conditions curtail photosynthesis in the primary unit, the secondary cell would continue this process and maintain high effluent quality if light is not too restricted by prolonged ice and snow cover.

Construction of such an in-series facility will usually entail less expense than a single cell large enough to give the desirable winter loading. For example, a community with a daily waste load of 180 lb BOD could be served by two 3-acre cells if latitude allows application of 60 lb/acre to the primary unit. Nine acres would be needed for a BOD loading of 20 lb/day/acre.

In the Fayette ponds, measurable oxygen was produced only by photosynthesis, absorption from the atmosphere being wholly inadequate to cope with more than a fraction of the decomposition-respiration requirements at any season. Intensity of photosynthesis was controlled by several factors. The most important physical feature was amount of light reaching the water. Observations indicate that optimum rate of loading for oxygen maintenance in primary cells could be readily related to intensity of available light if the latter factor had a consistent annual pattern. However, several variables contribute to its lowest yearly intensity and no definite minimum figure may be considered reliable. The annual solar radiation minimum on a langleys-per-day-per-month basis would appear to be a reasonably reliable standard, assuming uniform energy loss on a percentage basis, for areas where ice and snow covers are rare or unknown. With one exception, no sewage loading applied at Fayette produced an oxygen demand equal to rate of photosynthetic supply until ice cover reduced quantities of light available from solar radiation. Prior to development of ice cover, O_2 disappeared from four cells for one day after solar radiation reached a low of 41 langleys

TABLE XVIII.—Minimum Monthly Solar Radiation Levels (Average Number of Langleys Per Day) at Accredited Weather Bureau Stations

Station	Lat. ° ′	Long. ° ′	Period of Record	Average of Minimum Monthly Values	Months with Annual Minima	Lowest Minimum Monthly Value		
						Value	Month	Year
				(*a*) West Coast				
Barrow, Alaska	71 18	156 47	1951–58	6	Jan., Feb., Nov., Dec.	0	Dec.	1951, 52
Aklavik, Mackenzie	— —	— —	1950–58	21	Jan., Sept., Nov. Dec.	2	Dec.	1950, 55
Fairbanks, Alaska	64 46	147 52	1950–58	8	Jan., Dec.	5	Dec.	1950, 54, 55, 57
Matanuska, Alaska	61 34	149 17	1954–58	17	Dec.	15	Dec.	1954, 57
Bethel, Alaska	60 47	161 43	1950–58	31	Feb., Dec.	18	Dec.	1958
Annette, Alaska	55 02	131 34	1951–58	42	Jan., Dec.	31	Dec.	1956
Spokane, Wash.	47 37	117 31	1950–58	137	Sept., Nov., Dec.	70	Dec.	1958
Seattle, Wash.	47 32	122 18	1950–58	62	Jan., Dec.	51	Jan., Dec.	1953
Great Falls, Mont.	47 29	111 21	1950–58	117	Dec.	88	Dec.	1957
Seattle-Tacoma, Wash.	47 27	122 18	1952, 53, 56–58	58	Jan., Dec.	44	Jan.	1953
Prosser 4, NE, Wash.	46 15	119 45	1953–57	101	Jan., Dec.	80	Dec.	1956
Astoria, Ore.	46 09	123 53	1953–58	76	Jan., Dec.	67	Dec.	1957, 58
Boise, Idaho	43 34	116 13	1950–58	115	Jan., Dec.	93	Dec.	1955
Medford, Ore.	42 22	122 52	1950–58	90	Jan., Dec.	75	Dec.	1956
Salt Lake City, Utah	40 46	111 58	1950–53	128	Jan., Dec.	66	Dec.	1950
Ely, Nev.	39 17	114 51	1950–58	228	Jan., Feb., Dec.	200	Dec.	1950
Davis, Calif.	38 32	121 45	1950–58	126	Jan., Nov., Dec.	98	Dec.	1955
Fresno, Calif.	36 46	119 42	1950–58	163	Jan., Dec.	123	Dec.	1950
Las Vegas, Nev.	36 05	115 10	1950–58	257	Jan., Dec.	225	Dec.	1951
Inyokern, Calif.	35 39	117 49	1950–58	288	Jan., Dec.	237	Dec.	1952
Santa Maria, Calif.	34 54	120 27	1950–58	248	Jan., Dec.	206	Dec.	1955
Riverside, Calif.	33 58	117 20	1950–58	263	Jan., Dec.	227	Dec.	1950
Los Angeles, Calif.	33 56	118 23	1951–58	231	Jan., Dec.	183	Dec.	1955
Phoenix, Ariz.	33 26	112 01	1950–58	287	Jan., Dec.	242	Jan.	1957
Tucson, Ariz.	32 14	110 57	1955–58	297	Jan., Feb., Dec.	262	Jan.	1957
Pearl Harbor, Hawaii	21 21	157 57	1950–52	354	Jan., Dec.	332	Dec.	1951
Wake Island, Pac. Area	19 17	166 39	1951–58	421	Jan., Aug., Dec.	209	Dec	1953
Canton Island, Pac. Area	02 46	171 43	1951–58	518	Jan., May, June, July, Dec.	415	Jan.	1958

TABLE XVIII.—*Continued*

Station	Lat. ° ′	Long. ° ′	Period of Record	Average of Minimum Monthly Values	Months with Annual Minima	Lowest Minimum Monthly Value		
						Value	Month	Year
(b) West Central								
Resolute Bay, N.W.T.	— —	— —	1951, 54, 56–58	35	Jan., Mar., Oct., Nov., Dec.	0	Jan., Dec.	1951
Edmonton, Alberta	— —	— —	1950–58	67	Dec.	56	Dec.	1953, 56
Winnipeg, Manitoba	— —	— —	1950–58	95	Dec.	88	Dec.	1952, 57
Glasgow, Mont.	48 13	106 37	1950–53, 55–58	187	Jan., Feb., Apr., Dec.	108	Dec.	1957
Bismarck, N. D.	46 46	100 45	1950–58	141	Jan., Oct., Dec.	111	Dec.	1956
Rapid City, S. D.	44 02	103 03	1950–58	159	Dec.	137	Dec.	1951
Lander, Wyo.	42 48	108 43	1950–58	198	Jan., Dec.	168	Dec.	1958
Lincoln, Nebr.	40 49	96 42	1951–55, 57, 58	177	Jan., Nov., Dec.	160	Dec.	1954
Grand Lake, Colo.	40 16	105 49	1950–53, 55, 57, 58	197	Jan., Aug., Dec.	91	Dec.	1957
Grand Junction, Colo.	39 07	108 32	1951–58	214	Dec.	186	Dec.	1955
Dodge City, Kans.	37 46	99 58	1951–58	240	Jan., Dec.	217	Jan.	1957
Stillwater, Okla.	36 10	97 05	1950–57	205	Jan., Dec.	164	Jan.	1952
Oklahoma City, Okla.	35 24	97 36	1950–58	231	Jan., Dec.	178	Jan.	1957
Albuquerque, N. Mex.	35 03	106 37	1950–58	288	Jan., Dec.	263	Jan.	1957
Forth Worth, Tex.	32 50	97 03	1950–58	244	Jan., Nov., Dec.	190	Jan.	1957
Midland, Tex.	31 56	102 12	1954–58	274	Jan., Dec.	256	Jan.	1955
El Paso, Tex.	31 48	106 24	1950–58	322	Jan., Dec.	297	Dec.	1951
San Antonio, Tex.	29 32	98 28	1951–58	280	Jan., Nov., Dec.	190	Jan.	1957
(c) East Central								
Sault Ste. Marie, Mich.	46 28	84 22	1950–58	113	Sept., Nov., Dec.	77	Dec.	1957
St. Cloud, Minn.	45 35	94 11	1950–58	138	Jan., Nov., Dec.	109	Dec.	1956
Madison, Wis.	43 08	89 20	1950–58	118	Jan., Nov., Dec.	73	Dec.	1956
East Lansing, Mich.	42 43	84 28	1950–53, 55–58	97	Jan., Nov., Dec.	65	Dec.	1952
Ames, Iowa	42 00	93 39	1953–56	147	Dec.	136	Dec.	1955
Lemont, Ill.	— —	— —	1955–58	175	Jan., Feb., Dec.	132	Dec.	1955
Indianapolis, Ind.	39 44	86 16	1950–58	124	Jan., Dec.	98	Dec.	1956
Columbia, Mo.	38 58	92 22	1951–58	173	Jan., Nov., Dec.	105	Dec.	1952
Lexington, Ky.	38 02	84 36	1951, 54, 55, 57, 58	177	Jan., Dec.	158	Dec.	1954
Little Rock, Ark.	36 44	92 14	1951–58	178	Jan., Dec.	137	Jan.	1957
Nashville, Tenn.	36 07	86 41	1950–58	151	Jan., Dec.	126	Jan.	1950, 57
Lake Charles, La.	30 13	93 09	1950–58	226	Jan., Dec.	208	Jan.	1957
Brownsville, Tex.	25 54	97 26	1950–58	271	Jan., Nov., Dec.	218	Dec.	1958

TABLE XVIII.—*Continued*

Station	Lat. ° ′	Long. ° ′	Period of Record	Average of Minimum Monthly Values	Months with Annual Minima	Lowest Minimum Monthly Value		
						Value	Month	Year
			(*d*) East Coast					
Caribou, Me.	46 52	68 01	1950–58	107	Jan., Nov., Dec.	86	Dec.	1953
Ottawa, Ont.	— —	— —	1950–58	105	Jan., Nov., Dec.	88	Dec.	1953
Toronto, Ont.	— —	— —	1950–58	97	Jan., Dec.	78	Jan.	1950
Portland, Me.*	43 39	70 19	1950–58	218	Jan., July, Oct., Nov., Dec.	112	Dec.	1956
Schenectady, N. Y.	42 50	73 55	1951–58	95	Jan., Dec.	19	Dec.	1957
Ithaca, N. Y.	42 27	76 28	1950–58	96	Jan., Dec.	66	Dec.	1956
Boston, Mass.	42 22	71 01	1950–58	118	Jan., Nov., Dec.	99	Dec.	1956
Blue Hill, Mass.	42 13	71 07	1950–58	129	Jan., Nov., Dec.	110	Dec.	1954
East Wareham, Mass.	41 46	70 40	1950–56	135	Jan., Dec.	108	Jan.	1950
Put-in-Bay, Ohio	41 39	82 48	1950–53	107	Jan., Dec.	83	Dec.	1952
Newport, R. I.	41 29	71 18	1950–58	138	Jan., Dec.	116	Jan.	1950
Cleveland, Ohio	41 24	81 51	1950–53, 55–58	139	Jan., Mar., Nov., Dec.	96	Dec.	1957
Upton, N. Y.	40 52	72 53	1950–57	148	Jan., Dec.	115	Jan.	1950
State College, Pa.	40 48	77 52	1950–58	115	Jan., Dec.	94	Dec.	1954
Sayville, N. Y.	— —	— —	1950–58	142	Jan., Dec.	106	Jan.	1950
New York, N. Y.	40 46	73 52	1950–58	126	Jan., Dec.	105	Dec.	1956
Columbus, Ohio	40 00	82 53	1951–57	94	Jan., Sept., Nov., Dec.	43	Dec.	1956
Seabrook, N. J.	39 30	75 14	1950–57	144	Jan., Dec.	111	Dec.	1956
Washington, D. C.	38 51	77 02	1950–58	159	Jan., Dec.	131	Dec.	1956
Greensboro, N. C.	36 05	79 57	1951–58	208	Jan., Nov., Dec.	165	Jan.	1957
Oak Ridge, Tenn.	36 01	84 14	1950–58	149	Jan., Dec.	116	Dec.	1952
Raleigh, N. C.	35 52	78 47	1950–52, 57, 58	212	Jan., Nov., Dec.	189	Dec.	1950
Cape Hatteras, N. C.	35 16	75 33	1950–58	216	Jan., Dec.	189	Dec.	1952
Atlanta, Ga.	33 39	84 25	1951–58	221	Jan., Dec.	194	Dec.	1955
Griffin, Ga.	33 15	84 16	1950–58	212	Jan., Feb., Dec.	184	Dec.	1953
Charleston, S. C.	32 54	80 02	1950–58	218	Jan., Dec.	185	Dec.	1958
Apalachicola, Fla.	29 44	84 59	1950–58	261	Jan., Nov., Dec.	233	Dec.	1951
Gainesville, Fla.	29 38	82 22	1950, 51, 55–58	252	Jan., Dec.	209	Jan.	1958
Tampa, Fla.	27 58	82 32	1951–58	305	Dec.	260	Dec.	1958
Miami, Fla.	25 48	80 16	1951–58	314	Jan., Oct., Dec.	279	Dec.	1958
Swan Island, W. I.	— —	— —	1951–55, 57, 58	391	Jan., Aug., Nov., Dec.	340	Nov.	1953

* Check on local conditions strongly suggested here.

on December 17. Otherwise, the annual low monthly average of 161 langleys per day in December supplied adequate light for maintenance of oxygen in all units.

If ice cover need not be considered, it would appear that a minimum monthly solar radiation level averaging around 150 to 160 langleys per day would furnish enough light to maintain oxygen in ponds loaded up to 100 lb BOD/day/acre. This relationship suggests that a minimum of 1.5 langleys per day are needed for each pound of BOD applied per acre. Thus, to allow a safety factor, it would appear reasonable to divide the lowest daily average langleys per month by 2 to arrive at a preliminary load estimate (lb BOD/day/acre) for any ice-free area where it is possible to secure representative solar radiation records.

Table XVIII has been developed from U. S. Weather Bureau records covering all North American and some insular solar radiation stations that have been in operation since 1950. This table divides the continent into four north-south areas (by longitude) and lists average and lowest minimum monthly solar radiation levels recorded at individual stations in each area. For regions without ice cover, it appears that a generally successful BOD loading rate for primary ponds may be arrived at by dividing either the average or lowest minimum monthly solar radiation value by 2, depending on the required degree of assurance against oxygenless effluents. Such application of radiation data would necessarily assume adequate mixing of lagoon liquid to allow most efficient utilization of solar energy. If ice cover is the normal winter condition, minimum solar radiation figures can give only general load indications that will require modification by local observations and applied judgment.

Ice cover that endures for more than a few days introduces possibilities for a number of variables that would reduce loading to zero if due allowance were made for each in application of the foregoing solar radiation-load ratio. Intensity of solar radiation is therefore an unreliable guide to optimum rate of loading under this condition, as oxygen may endure for a month or disappear within a few days after the onset of ice cover as dictated by transparency of ice, depth of snow cover, etc. During the winter of 1957–58, a 60-per cent reduction of the load suggested by the minimum solar radiation level appeared necessary for maintenance of oxygen under an ice cover that lasted 36 days at Fayette. More snow cover could have reduced concentration to zero in all cells. To be safe, oxygen loss should be accepted as the normal course of events in primary ponds that will be covered with ice for appreciable periods. Winter loading under this condition should be kept at the minimum practicable level, which now appears to be about 20 lb BOD/day/acre. Series operation is indicated for maximum protection of effluent quality under these conditions.

Suggested criteria for determination of optimum loading rate have been advanced by Oswald and Gotaas (13), Gloyna and Hermann (14), Hermann and Gloyna (15), and others. Oswald and Gotaas developed a formula to indicate fraction of available light that could be expected to be utilized. This process appears somewhat involved and must be based on intensity of solar radiation at various latitudes. Some general considerations affecting rate of loading are presented in (14) and a formula for determining volume that considers number of people, BOD concentration of raw waste, and temperature is developed in (15).

Summary

Objectives of this investigative phase were performance as judged by effluent quality and degree of nuisance development, efficiency as related to loading and climatological factors, most

favorable rate of loading, and additional information on processes and interrelationships. Loading was established at levels of 20, 40, 60, 80, and 100 lb BOD/day/acre in a multiple-cell facility. Effluents and excess raw sewage from loading of these 1-acre cells were discharged to a 15-acre unit that produced the final effluent.

Lagoon bottoms allowed no detectable water loss after operational levels were established. Algae developed a few days after sewage introduction, and green water color was maintained uninterruptedly for more than a year. Floating blue-green algal mats developed in summer months, especially in lighter loaded units. Ice cover endured for as long as 36 days. Some sulfide odor was developed following oxygen loss under ice cover, which occurred at loadings of 60 + lb BOD/day/acre.

Chemically, the ponds displayed the usual alternation of dominance between photosynthesis and respiration-decomposition, with each type of process using by-products of the other to conserve energy and alter pH, alkalinity, and oxygen in its own manner as the opportunity arose on a daily and seasonal basis. As would be expected, photosynthesis was dominant during daylight hours until light supply to water was reduced by ice and snow cover. Decomposition-respiration was dominant at night and under ice as the cover became more opaque. Phosphorus was largely utilized in the PO_4 state and nitrogen as ammonia.

Phytoplankters were predominantly green algae and euglenophytes. One diatom and two blue-green algae were the only others noted. *Euglena proxima* and its variety *amphoraeformis* exhibited the greatest adaptability to lagoon conditions. Various Chlorococcales and *Chlamydomonas* were other frequent and abundant residents. *Chlamydomonas* and *Euglena* were the first to appear.

Phytoplankton numbers and volumes often differed widely. Production of these algae increased with load up to 60 lb BOD/day/acre and then leveled off. Various other features associated with their concentration and activities are described.

The entire facility displayed outstanding performance in removal of various sewage components and maintenance of a high-quality, oxygen-rich effluent. All individual units were equally efficient until ice cover reduced photosynthesis. Performance then declined in units with raw sewage loads of 60 to 100 lb BOD/day/acre. The large cell acted as a secondary in-series unit in many respects and increased oxygen production when other units entered winter declines. All cells had average coliform-type bacteria removals in excess of 99.99 per cent. Removal of BOD averaged more than 80 per cent in all units; alkalinity was decreased over a range of 39 to 43 per cent; nitrogen utilization varied from 94 to 98 per cent of quantities contained in raw sewage; and phosphorus reduction had a range of 83 to 92 per cent.

Performance and energy relationships indicated a dominant role by photosynthesis and the necessity of this process for occurrence of free oxygen. In-series operation appears more dependable for maintenance of effluent quality than use of a single cell. A tentative method for determination of a preliminary loading figure on the basis of solar radiation is presented. This method is aimed at maintenance of oxygen in cells receiving raw sewage in areas free from ice cover.

Acknowledgments

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SLUDGE DISPOSAL AT ALEXANDRIA

Samuel W. Shafer

The Alexandria Sanitation Authority operates an 18-mgd, high-rate, single-stage treatment plant which serves all but a small section of the City of Alexandria plus an adjacent area in Fairfax County, Virginia. Principal components of the plant include lift pumping, mechanical screening and grit removal, primary settling, trickling filtration, final settling, two-stage sludge digestion, and mechanical sludge dewatering. High-rate filtration is effected by recirculating a portion of the trickling filter effluent to the influent end of the primary settling tanks. Digester gas is utilized as fuel for engines driving three of the five sewage lift pumps and for building and digester heating. Final effluent is discharged indirectly to the Potomac River by way of Hunting Creek. The plant is currently operating at about one-half of its design capacity.

Description of Facilities

Sludge disposal facilities include elutriation, chemical conditioning, and vacuum filtration. Sludge cake is stockpiled on the plant property and is available to the public at no charge for use as a soil conditioner.

Elutriation is accomplished in two conventional settling tanks, 67 ft long, 14 ft wide, and 13½ ft deep (Figure 1). At the inlet of each tank is a mixing chamber equipped with vertical paddle mixers. Treatment plant effluent is used as the eluent, or wash water, and the elutriate is returned to the plant inlet to be treated as part of the sewage flow. Sludge is removed from the tanks with conventional collection equipment.

In this plant two-stage counter-current elutriation is practiced as follows: Digested sludge enters the mixing chamber of the primary elutriation tank together with the effluent, or elutriate, from the secondary. The mixture passes into the tank where the sludge solids settle to the bottom and the spent wash water returns by gravity to the plant inlet. The settled sludge is transferred to the secondary elutriation tank where it is mixed with fresh wash water and allowed to resettle. The resettled sludge is then pumped to the vacuum filters and the effluent is transferred by gravity to the primary elutriation tank. To summarize, the sludge receives two separate washes with the same water, the second wash being with clean water.

Two complete filtration units, each consisting of a sludge feed pump, ferric chloride solution tank and feed pump, conditioning tank, vacuum filter, vacuum pump, and filtrate receiver and pump, are provided (Figures 2 and 3). A single lime-feeding system serves both units. The filters are 10 ft in diameter and 10 ft long, with a total surface area of 300 sq ft. The filtering medium consists of two overlapped layers of stainless steel coil springs which are continuously cleaned with water sprays. The filter vats are equipped with reciprocating agitators

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The paper was given at the 14th Annual Meeting of the Virginia Industrial Wastes and Sewage Works Assn. in Richmond, June 15–16, 1960.

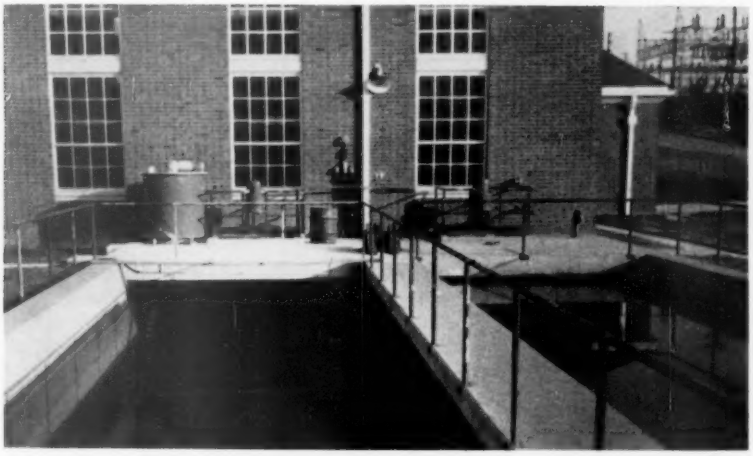

FIGURE 1.—Elutriation tanks and lime feed equipment.

which may be operated independently of the drum drive. The vacuum pumps are the rotary, water-seal type, producing a maximum vacuum of 13 in. of mercury (Figure 4).

In normal operation one filter operated six hours per day, five days per week is sufficient to handle the present volumes of digested sludge produced. Elutriated sludge is pumped to the conditioning tank where lime and ferric chloride are added. The mixture of sludge and chemicals is gently mixed with a mechanical agitator in the con-

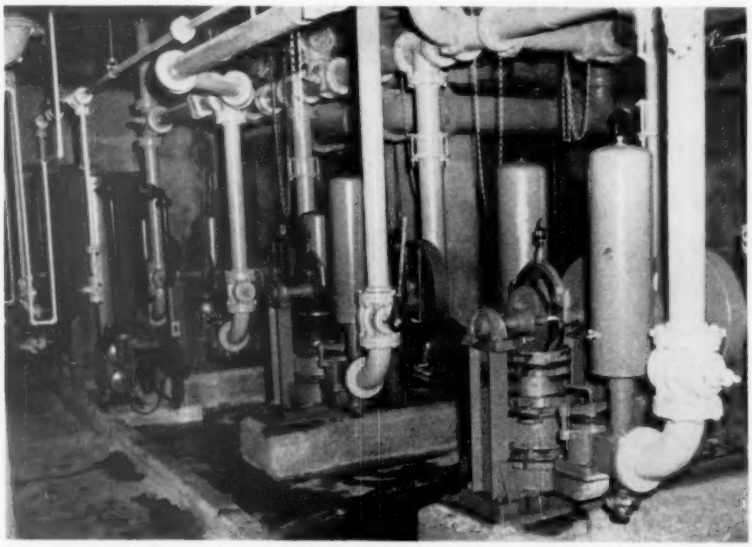

FIGURE 2.—Ferric chloride tanks and feeders, filter feed sludge pumps, and elutriated sludge transfer pumps.

ditioning tank to allow coagulation of the fine sludge particles and flows by gravity to the filter vat. The dewatered sludge cake is removed to a loading hopper by way of belt conveyors and hauled by truck to the stockpile area.

The sludge disposal facilities were placed in routine service in February of 1957, following acceptance tests conducted by the manufacturer. It is appropriate to mention that since that time, the mechanical equipment has functioned perfectly with no breakdowns encountered. Experience during the first few weeks, however, indicated that certain improvements could be made to produce greater operating efficiency. The balance of this paper will attempt to describe additions and changes which have been made, and operating techniques which have been developed in the past three and one-half years of operating these facilities.

Initial Changes

Lime Handling

One of the first improvements to be made was the installation of lime mixing and feeding equipment. Although the original design contemplated that the elutriation system would obviate the need for conditioning with lime, it became readily apparent that elutriation alone would not produce the desired results. Accordingly, a slurry tank and diaphragm-type variable speed pump, which had been rented from the filter manufacturer for feeding lime to the digester during initial startup, were purchased outright and permanently installed. In order to split the flow of lime slurry equally between the two conditioning tanks to enable operation of both filters at the same time, a single discharge line was carried from the feed pump to a point exactly between the two conditioning

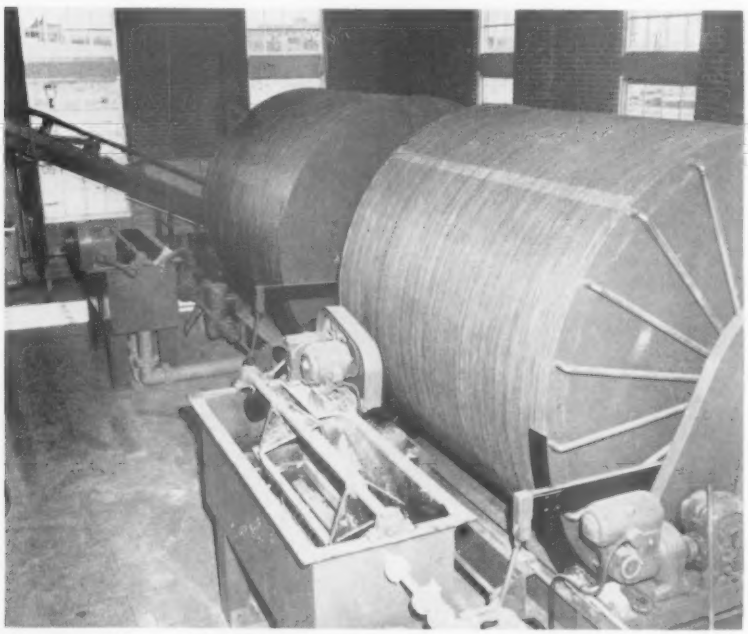

FIGURE 3.—Vacuum filters and conditioning tanks. The inclined conveyor belt is shown at the far end.

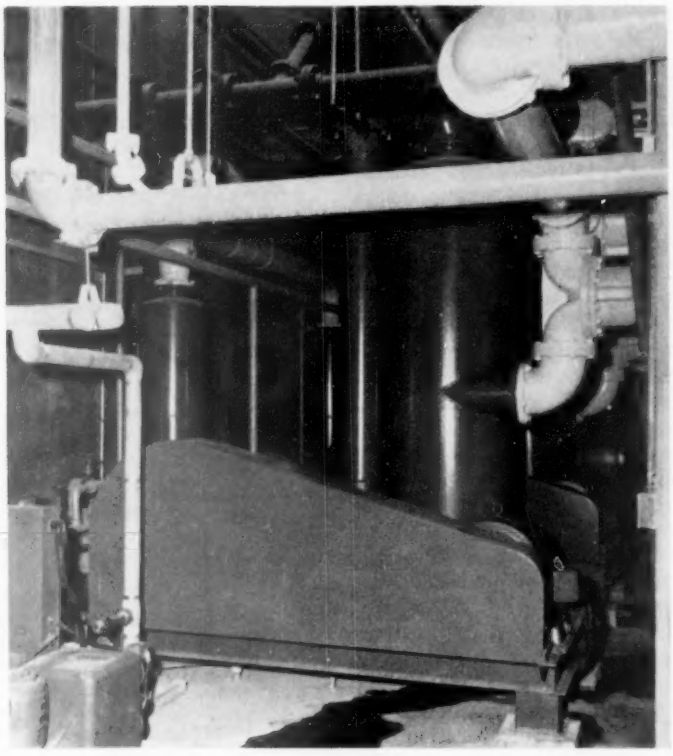

FIGURE 4.—Vacuum pumps for vacuum filters.

tanks from which branch pipes of equal lengths with identical fittings were run to each tank. This arrangement worked satisfactorily until unequal scaling in the branch lines created a difference in head conditions which resulted in unequal distribution between the two tanks. This was subsequently corrected by installing a small day-tank with valved discharge on each conditioning tank, permitting individual control of lime flow.

Ferric Chloride

The handling and storage of ferric chloride posed another early problem. Although facilities were installed for unloading, storage, and handling of the chemical in either anhydrous or solution form, the absence of a rail siding into the plant site appeared to preclude the use of the solution. However, after a few days of handling and mixing anhydrous ferric chloride and attempting to cope with the accompanying housekeeping problems, ways and means for transporting liquid to the plant were urgently sought. Fortunately, 5,000 gal of storage capacity in two rubber-lined tanks had been provided, otherwise the use of liquid could not have been contemplated. It was learned from the chemical manufacturer that the solution could be shipped in tank car quantities as small as 4,000 gal, or in tank trucks of 3,500-gal capacity. Since no means were immediately available for unloading and transporting the material from the nearest rail siding to the plant, tank truck delivery was selected. Although freight rates for truck trans-

portation were appreciably higher than rail rates, the total delivered cost on a dry weight basis was still less than the delivered cost of the anhydrous form. Accordingly, a trial order was placed.

The first experience with the tank truck transportation proved unsatisfactory because of the undue delays caused by weather and load size restrictions imposed by various state regulations. It was also found that shipping dates were scheduled more at the convenience of the trucker than the customer. Since ferric chloride solution could be shipped by rail in quantities compatible with storage capacity available at the plant, solution of the local transportation problem was all that was necessary to make this cheaper and more dependable method of delivery available. Accordingly the local tank truck companies were canvassed, and a firm with the equipment and the desire for the business was finally found. A tank car order was then placed, and the subsequent delivery was entirely satisfactory. This method of ferric chloride delivery is now in its third year of successful operation and has resulted in savings averaging $2,000 per year over the cost of the anhydrous chemical.

Scum Control

Control of scum formation on the surface of the primary elutriation tank was another problem to be resolved. Although surface scum did not interfere with the elutriation process, it did result in an excessive carry-over of solids in the tank effluent being returned to the plant inlet. To prevent the carry-over, a vertical baffle projecting about three or four inches beneath the liquid level was installed about a foot upstream from the effluent weir. A surface spray system was then installed to disperse the scum. The sprays act to release entrained gas from the solids particles, permitting them to settle.

Another minor improvement was made by connecting the filtrate discharge piping to the inlet of the secondary elutriation tank. It is believed that the residual lime and ferric chloride in the filtrate aid settling in the elutriation tank.

Process Control

Of primary importance to the success of the conditioning and dewatering process is the proper control of materials and equipment. Daily, and sometimes even hourly, variations in sludge consistency require frequent adjustment of chemicals and solids feed rates, drum speeds, etc. At the Alexandria plant a great deal of attention has been given to the development of operating techniques and the perfection of control procedures.

Maintaining the proper ratios of chemicals to sludge is probably the most important phase of mechanical dewatering. Too much or too little chemicals will result in over- or under-conditioned sludge which dewaters with difficulty, if at all.

Prior to placing the sludge disposal facilities in service a series of Buchner funnel tests was run to determine the optimum feed rates of lime and ferric chloride to be used. On the basis of the tests, starting rates of 3-per cent ferric chloride and 8-per cent lime were used. These rates proved successful in the initial operation and have not been varied appreciably since.

Although ferric chloride and lime are fed in solution and slurry forms, respectively, feed rates are determined on a dry weight of chemicals to dry weight of sludge solids basis. It was, therefore, necessary to provide the operating personnel with means for on-the-spot determinations of solution strengths and total sludge solids concentrations, and with means for quantitative control of sludge and chemical flow rates.

Elutriated sludge is fed to the condi-

tioning tanks with variable speed plunger pumps. Remote controls permit the operator to vary the pump speed at the panel board on the operating floor of the building. A tachometer for each pump is also installed on the control panel to provide quantitative regulation of pump speeds. In order to relate pump speed to discharge rate, discharge curves were plotted for each pump by timing the filling of a known volume in one of the conditioning tanks at various pump speeds.

It was then necessary to develop a quick method of sludge solids determination, the conventional methods being too time-consuming to use for on-the-spot control. Several schemes to accelerate the evaporation of moisture from the sludge samples were tried, but all proved unreliable. An attempt was also made to establish a usable relationship between solids content and the degree of separation of solids from liquid after centrifuging a sample for a given period of time. This was also unsuccessful. A satisfactory scheme using spectrophotometric methods was finally worked out as follows:

1. 50 ml of elutriated sludge sample is diluted with 50 ml of distilled water.
2. 10 ml of this is further diluted to 1 liter with distilled water.
3. The optical density of the highly diluted sample is read on a colorimeter using a wave length of 600 mμ.
4. The optical density is translated to solids content using a previously prepared curve.

This test can be completed in a matter of minutes and has proven highly reliable for control purposes, the results usually falling within 5 per cent of the total solids value as determined with conventional procedures.

Ferric chloride solution strengths are determined quickly and easily by obtaining the specific gravity with a hydrometer and translating the reading to strength in pounds per gallon using published tables. The ferric chloride feed pumps are equipped with variable speed controls and tachometers similar to the sludge feed pumps. Lime slurry strengths are predetermined by adding specified amounts of lime to a given water volume in the slurry tank. Slurry feed rates are determined using a quart container and a stop watch, and controlled by varying the feed pump speed and throttling the discharge valves on the equalizing tanks.

Tables have been prepared from which solids and chemical feed rates can be computed in the field with a minimum of calculations. Samples of elutriated sludge are analyzed for solids content at regular intervals during the day and chemical feed adjustments are made accordingly.

Operating Techniques

During three years of operating the sludge dewatering facilities, a number of operating techniques were developed, some of which are supported by reported experiences at other plants; others of which may be peculiar to Alexandria's operation alone.

In the elutriation process, it has been found that sludge solids tend to gradate according to particle size and weight, with the coarser, heavier material at the bottom of the tank. Experience has also shown that heavier, denser sludge will condition and dewater more easily and with less chemicals than will lighter solids. It is, therefore, the practice at the Alexandria plant to maintain a sludge blanket of 5 to 6 ft in the secondary elutriation tank, this depth producing maximum concentrations of solids without overloading the collection equipment.

After varying the ratio of wash water to sludge over a wide range, it was determined that a 3 to 1 ratio provided optimum results, using the reduction of total alkalinity in the sludge

as a parameter of efficiency. Greater ratios do not increase alkalinity removals enough to justify the additional expense of wash-water pumping.

In the operation of the conditioning tanks it has been found that holding time and agitation should be kept to the barest minimum, even to the point of producing incomplete mixing of chemicals and only partial flocculation of sludge solids to allow for the mixing caused by turbulence in the piping between the conditioning tank and the filter vat. Excessive mixing will break down the floc as it is formed and will result in poor filterability. Various points of introduction of lime and ferric chloride into the conditioning tanks also were tried. It was found that feeding ferric chloride into the sludge stream at the tank inlet and adding lime at the middle of the tank downstream from ferric chloride produced the most favorable results. Ferric chloride solution is usually applied at its delivered strength; that is, approximately 40 per cent anhydrous by weight, although at times it is diluted to approximately 10 per cent by weight in day-tanks available for the purpose. Lime slurry is made up by adding 400 lb of high calcium hydrated lime to 300 gal of water. The slurry tank is equipped with mixing paddles to prevent settling.

In the filter vats it is necessary to maintain a drum submergence of about 12 in. at the lowest point for optimum performance. Greater submergence results in a thinner, wetter cake; lesser submergence causes an excessive loss of vacuum. The proper vat level is maintained by controlling sludge feed, regulating filter drum speeds, or a combination of the two. Operation of the vat agitators is also an important factor and should be held to a minimum to avoid destruction of the chemical floc. At Alexandria, running the vat agitators for only 30 to 45 sec every 10 or 15 min adequately distributes the conditioned sludge throughout the vats without breaking up the floc.

Continuous spray washing of the filter coils is necessary to prevent the buildup of solids within the coil windings. The important aspect of this operation is that the spray must be delivered at 50 psi or more to provide enough impact to dislodge the sludge particles. Strainers installed in the spray supply piping must be checked and cleaned frequently to assure adequate pressure. The filter coils are acid-washed once a year to remove chemical scale.

Records and Laboratory Control

The maintenance of detailed records and a comprehensive sampling program are essential parts of Alexandria's sludge disposal process. On the daily log sheet, hourly recordings are made of digested sludge and elutriating water quantities, chemical and sludge feed rates, and filter cake production. Hourly samples of incoming digested sludge, elutriated sludge, filter cake, filtrate, and elutriation effluent are collected, composited, and submitted to the laboratory for analysis. From this information daily computations of solids processed, chemicals used, filter yields, and solids returned to the treatment plant are made and entered on a monthly summary sheet. These data are valuable tools in maintaining efficient and economical operation.

Operating Results and Costs

In the 1958–59 fiscal year a total of 4,015 tons of wet sludge cake were produced. This represents an average filter yield of 6.8 lb of dry solids per square foot of filter area per hour. Average chemical feed rates were 2.9-per cent ferric chloride and 7.5-per cent lime, as calcium oxide, on a dry solids basis. The average moisture content of the sludge cake was 78 per cent. The elutriation wash water to sludge

ratio was maintained at approximately 3 to 1.

In the same period, total operating costs averaged $16.38 per dry ton of solids broken down as follows:

Labor	$ 8.10
Chemicals	6.42
Power and water	1.46
Miscellaneous	.40
Total	$16.38

These costs include the laboratory work incidental to the process but do not include general administrative costs.

Conclusion and Acknowledgments

Experience at the Alexandria plant has shown that mechanical dewatering of digested sludge is by no means a "seat of the pants" operation. Quantitative control and the maintenance and use of records are essential to the success of the process. Grateful acknowledgment is given for the effort and cooperation of G. E. Hoffman, Plant Superintendent, E. J. Mea, former Plant Chemist, and J. J. Dungan, Sludge Disposal Operator, in developing and putting to use the procedures above described.

MEETINGS OF INTEREST

June 19–21 **Rudolfs Research Conference,** Department of Sanitation, Rutgers University, New Brunswick, N. J. Dr. H. Heukelekian, Chairman, Dept. of Sanitation, Rutgers University.

June–July Training Courses at Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Chief Training Program, Robert A. Taft Sanitary Engineering Center, 4676 Columbia Parkway, Cincinnati 26, Ohio, or nearest PHS Regional office. June 19–30, "Aquatic Biology for Engineers"; July 10–Sept. 9, "Engineering Aspects of Radiological Health"; and July 24–28, "Recent Developments in Water Bacteriology."

June 25–26 **American Society for Testing Materials,** Chalfonte-Haddon Hall, Atlantic City, N. J.

June 25–28 **Eighth Industrial Waste Conference,** Delaware Inn, Honey Harbour, Ontario. Ontario Water Resources Commission, 72 Grenville Street, Toronto, Ontario.

June 26–30 **American Society for Engineering Education,** University of Kentucky, Lexington, Ky.

July 4–7 **National Society of Professional Engineers,** Olympic Hotel, Seattle, Wash. Kenneth E. Trombley, NSPE, 2029 K St., N. W., Washington 6, D. C.

July 16–21 **Summer Training Institute, Rutgers**—The State University, New Brunswick, N. J. Courses in Air Pollution, Radiological Health, and Water Quality Management. Conducted by the staff of the Public Health Service's Robert A. Taft Sanitary Engineering Center. S. C. Martin, U. S. Public Health Service, 42 Broadway, New York 4.

Sept. 3–8 **American Chemical Society,** 140th National Meeting, Chicago, Ill. American Chemical Society, 1155 16th St., N. W., Washington 6, D. C.

EFFECTIVENESS OF THE INTERCEPTION OF SEWAGE–STORM WATER MIXTURES

Walter G. Shifrin and W. W. Horner

Perhaps the largest and one of the most critical stream pollution problems existing in the United States today is that of the Missouri and Mississippi Rivers in the St. Louis metropolitan area. Huge quantities of both sewage and industrial wastes are discharged to these rivers from Missouri and Illinois communities, for the most part with no treatment.

Attention was first called to this problem by the Bi-State Development Agency in 1954 (1). Meetings and conferences followed; however, it has only been since early 1959 that real progress has been made toward the solution of this problem. As a result of action initiated by the States of Missouri and Illinois and the U. S. Public Health Service, the Surgeon General, acting under the provisions of the Federal Water Pollution Control Act, Public Law 660, held a conference in St. Louis on March 4, 1958. At this meeting, the necessary remedial actions and a timetable for their enactment were set forth.

As a first step to comply with the course of action outlined at this conference, The East Side Levee and Sanitary District, which encompasses some 13 incorporated areas in Madison and St. Clair counties of Illinois, and the Metropolitan St. Louis Sewer District, which includes the City of St. Louis, as well as 96 communities in St. Louis County, engaged professional assistance to develop plans for abating the pollution of the Mississippi River. Although the problems of these two agencies are in many ways quite different, they do have one major problem in common. Like many of the older systems throughout the country, many of their sewers are of the combined type, designed and constructed to carry both sanitary sewage and storm water runoff.

This paper presents a rational method for determining the amount of the mixture of sewage and storm water runoff which should be intercepted for treatment.

Background Data

Figure 1 shows a typical hydrograph covering a 7-day period for a combined sewer. This hydrograph was developed from actual measurements of the flow from one of the Metropolitan St. Louis Sewer District outlets during the summer of 1959. Initial inspection of this hydrograph shows a definite pattern of dry weather flow. The wide variations and the relative magnitude of the discharge due to surface runoff of rainfall on three of the seven days are also shown.

Figure 1 also shows that it would not be economically feasible to intercept and treat all of the sewage-storm water runoff mixture. In order to approximate the possible magnitude of

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The basic thought and initial work on this project were done by Mr. Horner prior to his death in September 1958.

The paper was presented at the 33rd Annual Meeting of the Water Pollution Control Federation in Philadelphia, Pa., October 2–6, 1960.

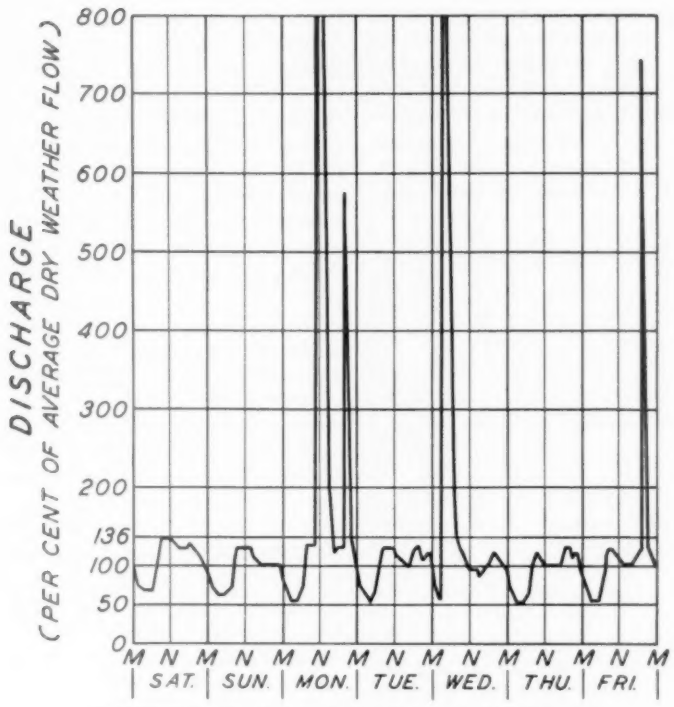

FIGURE 1.—Typical hydrograph for combined sewer.

storm water runoff for comparison with sanitary sewage flow, the following examples are presented.

Normally storm sewers are designed with sufficient capacity to carry away the surface runoff from a storm frequency of about once in 20 yr. In the St. Louis metropolitan area, the surface runoff from a 20-yr storm on a watershed which is 35 per cent impervious and has a 45-min concentration time would be about 2.0 in./hr. This runoff would be about 280 to 290 times the average sanitary sewage flow rate. If this same area were more "built-up" in nature, say 60-per cent impervious, the runoff from a rainstorm of the same intensity would be about 2.4 in./hr or approximately 340 times the average dry weather flow rate.

As pointed out by Camp (2), it has long been general practice to design interceptor sewers with capacities of from 2 to 5 times, and in rare cases even up to 10 times, the average dry weather flow of sanitary sewage. For typical large sewer systems such as those in existence in the St. Louis area, the ratio of the peak to the average dry weather sewage flow may be on the order of 1.3 : 1 to 1.4 : 1. In Figure 1 this ratio is 1.36 : 1. If five times the average dry weather flow were to be intercepted, this would result in an interceptor system being designed with capacity for about 3.7 times the peak dry weather flow.

At present it is estimated that the average dry weather sewage flow to the Mississippi River from sewers in the metropolitan St. Louis area is on the order of 180 cfs from the Illinois communities and 455 cfs from the Missouri side. The Mississippi River, with an average discharge of 167,000 cfs

and a minimum controlled flow of 45,000 cfs at St. Louis, affords on the average a dilution of 260 to 1, and a minimum dilution of 70 to 1. With this available dilution, it is obvious that occasional discharges of raw sewage mixed with surface runoff of rainfall will be insignificantly detrimental to the quality of the river water.

With the huge volumes of wastes to be handled in the metropolitan St. Louis area, the economic considerations relating to interception and treatment become extremely important. The available dilution of the Mississippi River, as well as the present and future downstream uses of the river, allow a liberalness not necessarily acceptable in other areas in determining the proper interception factor in terms of efficiency of treatment and economy of initial construction.

Basis of Study

The primary purpose of this study is to determine the proper interception factor, sometimes called the "dilution factor," especially with respect to runoff resulting from light rainfall, since it obviously is not economically feasible to intercept the huge quantities of surface runoff from heavy rainfalls. Therefore, it is necessary to study rainfall frequency and intensity in relatively small time intervals.

The meteorological data selected as the basis for this analysis are those obtained from the published records of the U. S. Weather Bureau (3). The period chosen for investigation was the year 1957, in which there was a wide variation in rainfall occurrence in the St. Louis area. Additionally, 1957 was an abnormally wet year, with precipitation about 140 per cent of normal.

The area originally selected for study was the watershed drained by the sewer system of the City of St. Louis. These sewers also serve some communities which lie in adjoining St. Louis County. For the most part, these sewers have been designed and constructed to carry the combined flow of sanitary sewage and storm water runoff to the Mississippi River for disposal. Large areas of St. Louis County are served by two of the City systems which deserve special consideration with respect to interception of the flow carried by them, because one is a separate system and the other is already served by a system of interceptors.

With the exception of these two systems, the area drained by the remaining combined sewer systems is approximately 25,300 acres. With an estimated future population of 680,000 persons, or 27 persons per acre, the estimated future average sewage flow, not including ground water infiltration, based on average water consumption for all types of usage, would be about 600 cfd/acre. To be comparable to rainfall, this flow was converted to the equivalent depth of 0.007 in./hr. Subsequent estimates of the ultimate average dry weather sewage flow, including infiltration, for the entire Mississippi River watershed of the Metropolitan St. Louis Sewer District confirm the foregoing value. Studies by McKee (4), Palmer (5), and Johnson (6), have reported that the average dry weather flow of sanitary sewage is approximately equal to the runoff from a rainstorm having an intensity of about 0.01 in./hr. This is in substantial agreement with the surface runoff quantity of 0.007 in./hr used in this study. Furthermore, based on actual flow measurements, the peak rate of sewage flow has been assumed to be 0.0095 in./hr, or approximately 136 per cent of the average flow.

Hydrologic Analysis of Surface Runoff

The procedure followed in this hydrologic analysis of surface runoff was first to tabulate on monthly computation sheets the hourly precipitation data for the entire year as extracted

from the Weather Bureau data. Runoff was then estimated for each hour of rain during the year.

All runoff estimates were based on the assumption that 35 per cent of the surface area is impervious, 65 per cent pervious. Based on previous studies (4) (5) and general experience, it was assumed, for the impervious area, that approximately 0.04 in. of depth is required to create a surface film before runoff can begin. The runoff from the impervious area was then calculated by deducting 0.04 in. from the initial hourly rainfall and then multiplying the remainder by 0.35. Except for the hot dry season, it was also assumed that the film of 0.04 in. accumulates through successive hours.

For the pervious area, it was assumed that the first 0.12 in. represents permanent surface retention, and that regardless of the condition of the ground, the first 0.12 in. in an hourly sequence would produce no runoff. In rainfalls of greater intensity, the infiltration rate in the first hour was generally assumed to be 0.50 in., and in the succeeding hour to be 0.25, reducing in continuing hours to a low value of 0.12. These are average values which have been developed in the past from research projects conducted under the direction of Horner (7) and Horner and Lloyd (8). However, for each particular application these figures for surface retention and infiltration were varied by judgment, recognizing antecedent conditions and related soil moisture.

The results of the foregoing calculations showed that out of the 8,760 hr in the year, measurable rainfall occurred in 626 hr, but runoff at a rate of 0.01 in. or more occurred in only 401 hr. These estimates of runoff were computed in increments of 0.01 in. up to 0.10 in./hr. For further analysis smaller increments in rate of runoff were desired, and a statistical analysis was made of the hours of rainfall and the rate of runoff. From this analysis it was possible to compute the runoff in increments of 0.0025 in., as shown in Table I, Columns 1 and 2. These computations show that of the 626 hr of rainfall in the year, 119 produced no runoff.

Analysis of Interceptor Efficiency

In Table I, computations have been carried out to evaluate the effectiveness of three interceptors of different capacities. The first interceptors had a capacity equal to the average sewage flow (0.007 in./hr) plus 0.0025 in./hr of rainfall runoff. This total capacity of 0.0095 in./hr also would be approximately equal to the peak sewage flow, or about 1.36 times the average dry weather flow. Interceptors with capacities equal to approximately 1.72 and 2.07 times the average sewage flow (127 and 153 per cent of the peak dry weather flow rate, respectively) also were analyzed.

The computation procedure used is as follows: Column 2 gives the adjusted hours of runoff at the indicated rate. In Column 3 the average sewage flow is added and the total rate of flow in the sewer is shown. Column 4 gives the calculated percentage of sanitary sewage in the total flow. In Column 5 the interceptor capacity has been deducted and the values represent that part of the flow which would overflow to the river. In Column 6 the overflow values from Column 5 are multiplied by the percentage of sanitary sewage in the flow to determine the amount of sewage being bypassed. In Column 7 the values in Column 6 are reduced to the equivalent number of hours of sanitary sewage flow at the average rate of 0.007 in./hr.

The significant results of Table I are summarized in Table II. For example, for an interceptor having a capacity equal to the peak sewage flow rate, it was determined that out of 8,760 hr in the year, rainfall occurred in 626, runoff greater than 0.0025 in./hr in 507, and overflowing of the inter-

TABLE I.—Analysis of Combined Sewage Discharged With Various Interceptor Capacities*

Surface Runoff Rate (1)	Adjusted Hours of Runoff (2)	Total Flow† (3)	Sewage in Flow (%) (4)	Interceptor Capacity 0.0095			Interceptor Capacity 0.012			Interceptor Capacity 0.0145		
				Flow to Outlet (5)	Sewage to Outlet‡ (6)	Equivalent Hours of Avg Sewage Flow§ (7)	Flow to Outlet (5a)	Sewage to Outlet‡ (6a)	Equivalent Hours of Avg Sewage Flow§ (7a)	Flow to Outlet (5b)	Sewage to Outlet‡ (6b)	Equivalent Hours of Avg Sewage Flow§ (7b)
(Increment 0.0025)												
0	119	0.0070	100	0	0	0	0	0	0	0	0	0
0.0025	72	0.0095	74	0	0	0	0	0	0	0	0	0
0.0050	57	0.0120	58	0.0025	0.0015	12.2	0	0	0	0	0	0
0.0075	44	0.0145	48	0.0050	0.0024	15.1	0.0025	0.0012	7.5	0	0	0
0.0100	34.5	0.0170	41	0.0075	0.0031	15.3	0.0050	0.0021	10.4	0.0025	0.0010	4.9
0.0125	27.5	0.0195	36	0.0100	0.0036	14.1	0.0075	0.0027	10.6	0.0050	0.0018	7.1
0.0150	22.5	0.0220	32	0.0125	0.0040	12.9	0.0100	0.0032	10.3	0.0075	0.0024	7.7
0.0175	19.5	0.0245	29	0.0150	0.0044	12.3	0.0125	0.0036	10.0	0.0100	0.0029	8.1
0.0200	16.5	0.0270	26	0.0175	0.0046	10.8	0.0150	0.0039	9.2	0.0125	0.0033	7.8
0.0225	14.8	0.0295	24	0.0200	0.0048	10.1	0.0175	0.0042	8.9	0.0150	0.0036	7.6
0.0250	13.0	0.0320	22	0.0225	0.0050	9.3	0.0200	0.0044	8.2	0.0175	0.0039	7.2
0.0275	11.8	0.0345	20	0.0250	0.0050	8.4	0.0225	0.0045	7.6	0.0200	0.0040	6.7
0.0300	10.5	0.0370	19	0.0275	0.0052	7.8	0.0250	0.0042	7.2	0.0225	0.0043	6.5
0.0325	9.8	0.0395	18	0.0300	0.0054	7.6	0.0275	0.0050	7.1	0.0250	0.0045	6.3
0.0350	9.0	0.0420	17	0.0325	0.0055	7.1	0.0300	0.0051	6.6	0.0275	0.0047	6.0
0.0375	8.3	0.0445	16	0.0350	0.0056	6.6	0.0325	0.0052	6.2	0.0300	0.0048	5.7
0.0400	7.8	0.0470	15	0.0375	0.0056	6.2	0.0350	0.0053	5.9	0.0325	0.0049	5.5
0.0425	7.3	0.0495	14	0.0400	0.0056	5.8	0.0375	0.0053	5.5	0.0350	0.0049	5.1
0.0450	6.8	0.0520	13	0.0425	0.0055	5.3	0.0400	0.0052	5.1	0.0375	0.0049	4.8
0.0475	6.3	0.0545	13	0.0450	0.0059	5.3	0.0425	0.0055	5.0	0.0400	0.0052	4.7
0.0500	6.0	0.0570	12	0.0475	0.0057	4.9	0.0450	0.0054	4.6	0.0425	0.0051	4.4
0 to 0.05	524	—	—	—	—	177.1	—	—	135.9	—	—	106.1

* Sewage flow in inches of depth per hour (average 0.007, peak 0.0095).

† Col. 1 + 0.007.

‡ Col. 4 × Col. 5.

§ $\frac{\text{Col. 2} \times \text{Col. 6}}{0.007}$.

TABLE I.—*Continued*

Surface Runoff Rate (1)	Adjusted Hours of Runoff (2)	Total Flow† (3)	Sewage in Flow (%) (4)	Interceptor Capacity 0.0095			Interceptor Capacity 0.012			Interceptor Capacity 0.0145		
				Flow to Outlet (5)	Sewage to Outlet‡ (6)	Equivalent Hours of Avg Sewage Flow§ (7)	Flow to Outlet (5a)	Sewage to Outlet‡ (6a)	Equivalent Hours of Avg Sewage Flow§ (7a)	Flow to Outlet (5b)	Sewage to Outlet‡ (6b)	Equivalent Hours of Avg Sewage Flow§ (7b)
(Increment 0.01)												
0.06	18.0	0.0670	10.4	0.0575	0.0060	15.4	0.0550	0.0057	14.7	0.0525	0.0055	14.1
0.07	15.0	0.0770	9.1	0.0675	0.0061	13.1	0.0650	0.0059	12.6	0.0625	0.0057	12.2
0.08	12.0	0.0870	8.0	0.0775	0.0062	10.6	0.0750	0.0060	10.3	0.0725	0.0058	9.9
0.09	9.0	0.0970	7.2	0.0875	0.0063	8.1	0.0850	0.0061	7.8	0.0825	0.0059	7.6
0.10	7.0	0.1070	6.5	0.0975	0.0063	6.3	0.0950	0.0062	6.2	0.0925	0.0060	6.0
0.06 to 0.10	61	—	—	—	—	53.5	—	—	51.6	—	—	49.8
(Increment 0.10+)	41	—	—	—	0.0069	40.4	—	0.0068	39.8	—	0.0067	39.2
Total	626	—	—	—	—	271.0	—	—	227.3	—	—	195.1

TABLE II.—Relation of Interceptor Capacity to Pollutional Discharge

Item	Interceptor Capacity 0.0095 in./hr	Interceptor Capacity 0.012 in./hr	Interceptor Capacity 0.0145 in./hr
Total hours per year	8,760	8,760	8,760
Hours of rainfall (1957)	626	626	626
Hours of runoff (1957)	507	507	507
Hours of mixed overflow	435	378	334
Equivalent hours of sewage overflow (@ 0.007 in./hr)	271	227	195
Per cent time of overflow	5.0	4.3	3.8
Per cent sewage discharged	3.09	2.59	2.23

ceptor 435 hr, or 5.0 per cent of the time. Actual sanitary sewage bypassed during these 435 hr is equivalent to 271 hr of flow at the average dry weather rate.

Figure 2 shows the results of the foregoing analysis. For an interceptor with capacity equal to the peak dry weather sewage flow (136 per cent of the average flow), only 3.09 per cent

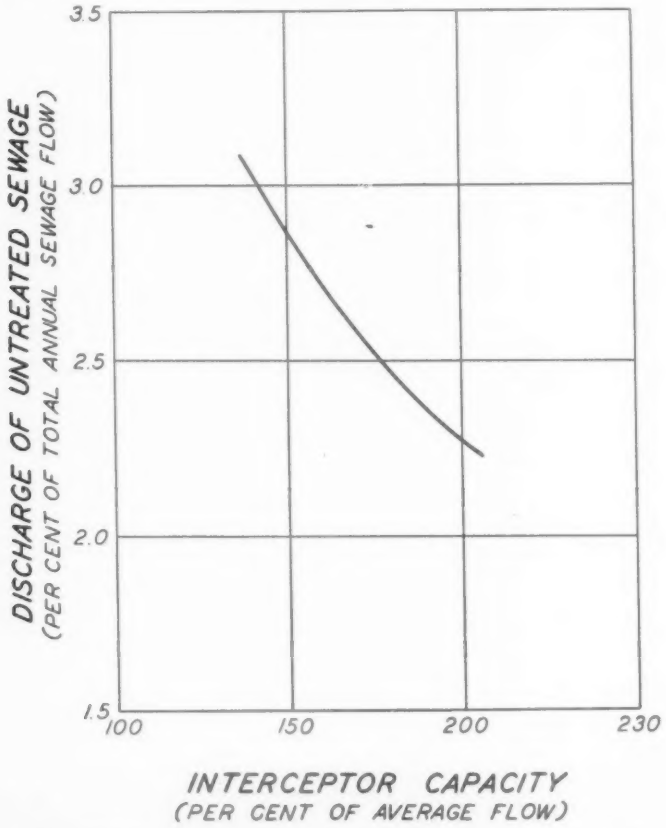

FIGURE 2.—Effectiveness of interceptors of different capacities.

of the dry weather flow would be bypassed to the receiving stream during the year if the selected pattern of rainfall (actual rains of 1957) occurred. If the capacity of the interceptor system were increased to twice the average sewage flow, or approximately 150 per cent of the peak flow rate, the amount of raw sewage which would be bypassed is only reduced by 0.86 per cent to 2.23 per cent. A corresponding reduction of only 1.2 per cent in the time of overflow is accomplished by this increase in interceptor capacity.

Further analysis of the runoff data shows that with the interceptor system designed with capacity equal to the peak sewage flow rate, there would have been 72 actual occurrences of bypassing, of which only 30 would have had a duration exceeding 6 hr. The maximum number of overflows in any one month was found to be 12. These findings are also in substantial agreement with those of McKee (4) for Boston, Palmer (5) for Detroit, and Johnson (6) for Washington, D. C.

Discussion of Findings

By going one step further, the effects of these interceptors of various sizes on the effectiveness of pollution abatement facilities may be shown. It is presently contemplated that primary treatment will satisfy the criteria set forth for treatment of wastes to be discharged to the Mississippi River in the St. Louis metropolitan area. It may normally be expected that if such facilities are properly operated and maintained, they will remove 90 per cent of the floating solids, 80 per cent of the settleable solids, 50 per cent of the total suspended solids, and 35 per cent of the 5-day BOD.

With an interceptor capacity of approximately 150 per cent of the peak flow rate, it was shown that 2.23 per cent of the total annual flow would be bypassed to the river. From the 97.8 per cent of the flow which would be intercepted and treated, 50 per cent of the total suspended solids would be removed, thereby effecting an over-all removal of 48.9 per cent. By providing an interceptor with a capacity equal to only the peak dry weather sewage flow rate, this efficiency would be reduced to 48.5 per cent. Figure 3 shows the effect of various size interceptors on the removal of other constituents of the waste flow. With the exception of floating solids, these curves are based on the percentages of sewage bypassed. The percentage of time in which overflow occurs was used to develop the curve for floating solids. This difference is due to the fact that some portion of the pollutants which are distributed throughout the volume of the mixture being discharged would be intercepted at all times, whereas all the floating materials would tend to be bypassed during periods of overflow. It may be seen that little increase in the effectiveness of the removal of the various pollutants results from increasing interceptor capacity. Also, for all interceptor capacities shown the over-all efficiencies indicated in Figure 3 lie within the aims of this program as stated by the Illinois Sanitary Water Board and the Missouri Water Pollution Board.

With respect to coliform removals, it is realized that during periods of overflow some pollution will result. However, because the Mississippi River downstream from St. Louis is not used for recreation except for power boating and is not a water supply source for many miles, this bacterial pollution during the 5 per cent of the time in which overflow occurs is not deemed serious. Furthermore, the Mississippi River has fairly high velocities and purges itself rapidly at all stages. Therefore, no justification is found for increasing the capacity of interceptors over that of peak dry weather flow to effect greater removals of coliforms when only primary treatment is to be provided. Kittrell (9) also has arrived at the same conclusion.

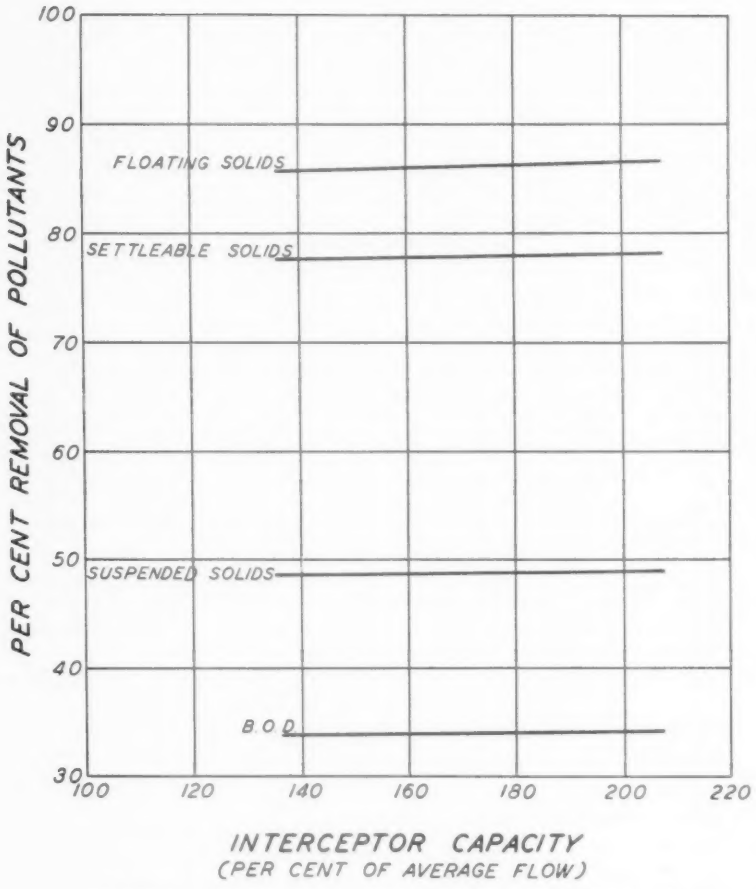

FIGURE 3.—Effects of interceptor capacity on effectiveness of pollution abatement.

Interceptor capacity obviously has a great effect on the capital as well as on the operating costs of interceptor and treatment facilities. The sizes of intercepting sewers, pumping stations, and the hydraulic elements of treatment plants are directly affected. It has been estimated that to provide interceptor capacity for approximately 150 per cent of the peak sewage flow rate (in other words, twice the average flow rate) the cost of sewers would be about 30 to 35 per cent greater than if capacity were provided for only the peak sewage flow rate.

Conclusions

Based on the foregoing analysis and findings, certain conclusions may be drawn. In evaluating these conclusions, it must be borne in mind that occasional discharges of raw sewage mixed with surface storm water runoff in the St. Louis area will be into the Mississippi River, which has a tremendous capacity for assimilating these discharges. For smaller and less turbulent streams, raw sewage discharges of the amounts proposed herein conceivably might adversely affect the quality of these streams and could not

be tolerated. Thus, for the conditions prevailing in the St. Louis area, it is concluded that:

1. The selection of interceptor capacities in excess of the peak dry weather sewage flow rate would produce an insignificantly small increase in the effectiveness of pollution abatement at a significant increase in the initial cost of the facilities.

2. For the ratio of peak to average dry weather sewage flow used in this study (peak flow equal to 136 per cent of the average sewage flow), or for any ratio in excess of that used in this study, there is no justification for adopting interceptor capacities in excess of the peak sewage flow rate.

3. For occasional high dry weather peaks of short duration, there may be justification for selecting interceptor capacities less than that of the peak flow rate.

A meeting was held in February 1959 for the purpose of presenting the foregoing conclusions to the water pollution control agencies involved; that is, the U. S. Public Health Service, the Illinois Sanitary Water Board, and the Missouri Water Pollution Board. After independent review, each of these agencies has given its approval to the findings of this study. Therefore, preliminary designs and cost estimates of sewage interception and treatment facilities for The East Side Levee and Sanitary District and for the Metropolitan St. Louis Sewer District are being prepared on the basis of providing interceptor capacity equal to the anticipated ultimate peak sewage flow rate.

Acknowledgments

The writers are deeply indebted to E. E. Bloss and E. C. Meserve for the work they performed on this study. Their assistance and sound advice are gratefully acknowledged.

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PROCEEDINGS OF NATIONAL CONFERENCE

The 600-page Proceedings of the National Conference on Water Pollution held in Washington last December 12–14 is available (PHS Publication No. 819).

The Federation has a few copies which are available singly to anyone making a request.

21. FLOW MEASUREMENT

No reasonably accurate evaluation of plant performance can be made without measuring sewage flows. Measurements of the total volume treated in a plant, or handled in sewers, in a day, week, or year, serve many comparative purposes and help chart trends and conditions to be reckoned with later. Information on total volume handled by individual operating units aids in the proper operation and maintenance of those units.

Specifically, flow measurements:

1. Provide information on operating efficiency, particularly unit operations, such as pumping, sedimentation, oxidation, disinfection, and digestion.

2. Make possible intelligent control of unit operations such as pump operations, dosage rates for trickling filters, aeration and return sludge in activated sludge, sludge loading on digesters, digester heating, sludge disposal operations (particularly elutriation, chemical dewatering, and incineration), and in chemical feeding.

3. Are used to ascertain quantity of sewage received from outlying communities or from industrial establishments; this is particularly necessary where charges for treatment are made against the outlying community or the industries.

4. Provide data for preparing records of performance.

21.1 FUNDAMENTALS OF FLOW MEASUREMENT

21.11 Quantity

In the case of fluids (liquids and gases), quantity is a measure of either volume or mass (weight) of a substance confined or contained in any given structure, vessel, tank, pipe, etc.

21.12 Flow

Flow is quantity in movement from one point to another (or past a point) in a specified interval of time. This fundamental idea of flow may be visualized from Figure 21–1, which shows a pipe connecting two tanks containing a liquid. When the valve at Tank 2 is closed, there is no movement of liquid from one tank to the other. Under these conditions the volume of the liquid in the pipe is represented by $V = A\ L$, in which V is volume, A is cross-sectional area, and L is the length of the pipe.

When the valve is opened, liquid moves because it is under pressure

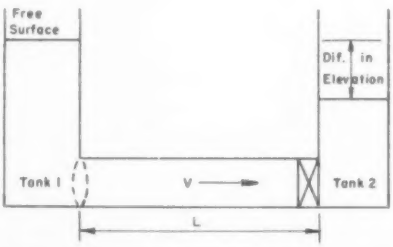

FIGURE 21–1.—Schematic diagram characterizing a concept of flow.

This is Chapter 21 of Operation of Sewage Treatment Plants, *Manual of Practice No. 11. Serialization began in the September 1960 issue.*

(head) since the liquid in Tank 1 is higher than in Tank 2. The quantity moving then becomes the number of times that the length of pipe, L is filled and emptied in a given period of time, T. Since L/T = velocity, then for flowing liquids

$$Q = A\,V$$

in which

Q = Volume per unit time, T;
A = Area; and
V = Velocity.

Velocity, or some function of it, therefore, is a fundamental factor in the measurement of flow. It is this basic concept on which flow measuring devices are based.

The term "rate of flow" is applied to measurements of quantity in motion for a unit of time; for example, per second, minute, or hour, and, sometimes, per day. Total flow, or volume, is the term applied to the total amount of liquid moved during any unit of time, usually referring to a period of a day, month, or year. Total volume is average rate of flow multiplied by the total time of flow. Rates of flow of liquids are usually expressed in one of these units: (*a*) cubic feet per second (cfs); (*b*) gallons per minute (gpm); or (*c*) million gallons per day (mgd). Total volume is expressed in cubic feet, gallons, or millions of gallons. Rate of flow for gases is usually expressed in cubic feet per minute (cfm).

21.13 Location of Metering Points

The location of metering devices within a sewage works, including the sewer system, is usually dictated by factors of design and information needed or desired for operation purposes. All plants, regardless of size, require some measurement or estimation of quantities and rates of flow for effective operation. Basic and other desirable measurements are listed in Table 21–1 according to type of treatment.

In view of the relatively low cost of metering equipment, it may often pay dividends to have extensive metering in all larger plants. Complete metering will assure availability of information on all phases of operation and make it possible to know the performance of the whole plant as well as its component parts. In the following sections is an outline of the meter locations for complete metering.

21.131 Sewers

1. Main sewers tributary to interceptors,

TABLE 21-1.—Helpful Flow Measurements

Type of Treatment	Basic Measurements	Other Desirable Measurements
Imhoff tanks and primary sedimentation	Sewage flow rate, volume sludge removed	
Separate sludge digestion	Volume sludge added per day, volume digested sludge, volume gas produced per day	Rate sludge added, rate sludge removed, rate supernatant removed, volume gas wasted per day, rate sludge recirculated
Chlorination	Rate chlorine feed	
Trickling filters	Volume sludge removed from final settling tank, recirculation rate	Rate sewage applied (if other than rate of raw sewage flow)
Activated sludge	Rate return activated sludge, rate sludge wasted, volume air added	
Miscellaneous	Electricity, volume gas purchased, volume fuel oil purchased	Volume water used

2. Tributary from outside municipality,
3. Tributary from industry,
4. Lift station discharge,
5. Sampling stations.

21.132 Pumping

1. Running-time meters,
2. Bypass lines,
3. Influent to individual settling tanks,
4. Settled sludge, drawn or pumped.

21.133 Disinfection

1. Chlorine,
2. Water for chlorination.

21.134 Sludge Digestion

1. Raw sludge added,
2. Digested sludge drawn,
3. Supernatant liquor drawn,
4. Gas volume produced,
5. Heating-water flow,
6. Recirculation through heat exchanger,
7. Gas burned for sludge heating.

21.135 Sludge Disposal

1. Sludge volume handled,
2. Sludge dewatering:
   (*a*) Elutriation water,
   (*b*) Elutriated sludge,
   (*c*) Dewatered sludge cake,
   (*d*) Filtrate liquor,
   (*e*) Chemicals.

21.136 Secondary Treatment

1. Activated sludge:
   (*a*) Influent to each aeration tank,
   (*b*) Return sludge to each tank,
   (*c*) Sludge from final clarifier,
   (*d*) Sludge to waste,
   (*e*) Air volume to each aeration unit,
   (*f*) Total air volume.
2. Trickling filter:
   (*a*) Influent to each filter,
   (*b*) Sludge from final clarifier,
   (*c*) Recirculated flow.

21.137 Miscellaneous

1. Electricity,
2. Fuel oil,
3. Potable water,
4. Plant water (effluent),
5. Gas used.

21.138 Measurements Other Than Flow

1. Temperature:
   (*a*) Atmosphere,
   (*b*) Plant influent,
   (*c*) Digester heating water,
   (*d*) Digester contents.
2. Barometric pressure,
3. Rainfall,
4. Wind direction and velocity,
5. Gas concentration alarms,
6. Pressure in pipelines,
7. Tank levels.

21.2 PRIMARY DEVICES FOR FLOW MEASUREMENT

The primary units in flow measurement are those which actually measure the flow (weirs, flumes, nozzle, etc.). Secondary units, usually called the secondary instrument or receiver, convert information sensed by and transmitted from the primary unit into usable information.

21.21 Fill-and-Draw Devices

The total quantity of a liquid can be determined if the liquid enters (or leaves) a vessel of known dimensions. The change in liquid level in a tank permits this measurement. This method has the limitation that no flow may leave the tank while it is being filled and vice versa.

Average rate of flow can be determined by dividing the volume entering or leaving a tank by the duration of flow. A bucket and a watch constitute the simplest tools necessary to measure rates of flow on a fill-and-draw basis.

The tipping bucket for measuring

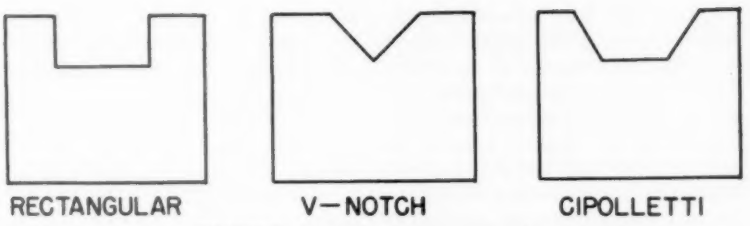

FIGURE 21-2.—Some common weirs.

digested sludge is another simple form of fill-and-draw device; a counter attached to the bucket will serve as a means of calculating the total quantity of flow. Rate of flow is seldom determined by a tipping bucket, but it could be done by timing the number of tips over a specified period.

21.22 Constant Differential Meters

The rotameter is a rate-of-flow indicator for liquids and gases. It consists of a tapered tube, smaller at the bottom than at the top, and a movable element called the "float," which rises in the tube as the flow through the tube increases. The difference in pressure below and above the float remains constant, and the position of the element gives a fairly accurate measure of instantaneous rate of flow. This device is not used for large flows.

21.23 Head-Area Meters

A head-area meter is a measuring device used only for open-channel flow or flow in partially filled pipes. It operates on the principle that a constriction or controlled barrier in the flow channel will cause an upstream rise in the liquid level (to force the liquid past the barrier). This head or elevation of the liquid above the barrier is a function of the velocity of flow and, therefore, of volume flowing through a known constriction per unit time.

21.231 Weirs:—A weir (Figure 21-2) consists of a bulkhead or dam containing a recess or notch, through which the sewage flows to fall freely to a level below the bottom of the recess or notch. Weirs are generally used in sewers and streams for flow measurement on a temporary basis.

Weirs may have many shapes, such as rectangular, V-notch, trapezoidal, and Sutro (proportioning weir). Weirs are generally sharp-crested so that the liquid will break cleanly from the crest (Figure 21-3), although broad-crested weirs may be used.

Determination of the head may be made in several ways: (*a*) a staff gage or rule, the zero mark of which is level with the crest of the weir; (*b*) a float gage; (*c*) a plumb bob on measured line lowered from a reference point until the tip just ripples the flowing surface; or (*d*) a hook gage, a metal hook raised from beneath until the point just breaks the water surface. Where the flow is turbulent, a stilling well may be used.

The V-notch weir is best suited for small flows and the angle of the notch is commonly 90 or 60 deg. The trapezoidal weir, particularly the Cipolletti weir, may be used where the channel is

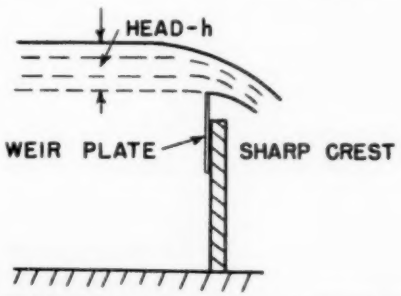

FIGURE 21-3.—Flow over sharp-crested weir.

large or where the head cannot be large with respect to the width of the weir.

For greater accuracy of measurement, all weir formulas need to be corrected for friction, contraction, and other factors. Tables and charts are available for determining the rate of flow if the head over the weir is known.

Weirs are recognized as inexpensive, simple devices, but they do have definite limits of use. Settleable solids, floating matter, and stringy material tend to either deposit in the approach area or collect on the crest itself.

21.232 Parshall Flume:—The Parshall flume is a widely used measuring device; it is an adaptation of the venturi flume, which was an adaptation of the venturi-tube principle to open-channel flow measurement.

The flume consists of an entrance section with converging walls and level floor, a constricted throat section with parallel walls and downstream sloping floor, and a recovery section with diverging walls and a rising floor. A specially located tap and stilling well are used in measuring the liquid height. Dimensions of Parshall flumes must be held to close tolerances. To improve the accuracy of construction, prefabricated liners are often used for the approach and throat sections.

Flow charts and tables as well as construction details are discussed in most references and handbooks on liquid measurement.

21.233 Flow Nozzle:—Flow nozzles are specially constricted outlets for placement at the end of a pipe flowing partially full. The design of the constriction is such that the depth of the liquid within the nozzle bears a definite relation to the flow. The discharge from the nozzle must be free.

Flow nozzles are factory-calibrated and have good accuracy over a wide range of flow. Where abnormal installations exist, calibration should be under conditions identical with field conditions. A connection can be made to the nozzle through a sediment trap to attach a direct-reading level gage or through a float well or pressure pipe to other types of mechanical gages.

Nozzles normally are self-scouring and will pass relatively large solids without clogging. Use of flow nozzles for heavy sludge, however, is not recommended unless calibration is for such use. Any deposition will alter the contour of the nozzle and its flow characteristics. For this reason the top of the nozzle is left open for inspection and cleaning.

21.24 Velocity Meters

A velocity meter consists essentially of a propeller in a pipeline. The propeller turns in direct relation to the velocity of fluid flow. Velocity meters, when used in open channel flow are called current meters.

21.25 Differential Head Meters

These meters are in common use and have good accuracy. They function by means of a change in pressure brought about by a constriction of flow. This pressure change can be related to rate of flow.

21.251 Venturi Tubes:—The venturi tube usually consists of several sections, including a conical reducing section, a cylindrical throat section, and a divergent outlet cone.

The accuracy of the venturi tube will normally be in the range of plus or minus two per cent. The velocity and direction of the flow in the pipe ahead of the meter can have a detrimental effect on accuracy.

21.252 Flow Tubes:—Another venturi-type differential producer is the Dall flow tube. It is an accurate primary device having a low permanent head loss.

21.253 Orifice:—The orifice meter consists of a thin flat plate with a hole in it. The hole may be circular at the

center of the plate (concentric), or tangent to the inside wall of the pipe (eccentric). Other variations also are available.

Caution is necessary in the location of orifice plates; they must be placed in a straight run of pipe with no fittings for 10 to 15 pipe diameters upstream or for 5 diameters downstream. If swirls or spirals exist in the flow stream as it approaches the orifice, longer lengths of straight-run pipe are required or straightening vanes must be used.

Orifice plates, like weirs, are, in effect, dams behind which solid particles will deposit from liquids containing settleable solids. They are seldom used for measuring sewage, but are used for gas.

21.3 SECONDARY INSTRUMENTS AND CONTROLS

The secondary unit of a meter, usually called the secondary instrument (or receiver), is a device used to convert information sensed by and transmitted from the primary unit into desired information. Liquid levels and pressure also can be shown on secondary instruments.

Secondary instruments are classified by (*a*) type of information desired and (*b*) method of transmission used from primary to secondary instruments.

There are three kinds of information that can be obtained from secondary instruments, either separately or in any combination:

1. Indication of flow rate,
2. Running total of flow passing a point,
3. A record on a chart, showing the rate of flow as a continuous record for each instant throughout the particular period of observation.

These instruments are called, respectively, indicator, totalizer, and recorder. Combinations of these functions are common; the most common being the totalizer-recorder, although the totalizer-indicator-recorder is also quite common in sewage works. The choice of any one of these types depends on the objective of measurement. For example, a plant influent meter might be a totalizer-indicator-recorder; an aeration tank air meter might be an indicator-recorder; and a digester cover level gage might be an indicator only.

21.31 Transmission

There are three types of secondary instruments, designated according to the method of transmitting the information from the primary—mechanical, electrical, or pneumatic.

A mechanical meter is one that is actuated by a float or directly by differential pressure. In float actuation, the instrument is mounted near a stilling well and the change in liquid level is transmitted by means of a float, cable, and counter-weight. In differential actuation, pressure pipes are run directly from the differential producer to mercury wells of the secondary instrument.

If the secondary instrument cannot be located near the primary unit stilling well, or if there is insufficient head to utilize direct connection with the secondary instrument, then electrical or pneumatic transmission may be used.

Electrical transmission is usually of the time-impulse type. The transmitter is a device which contains a cam, synchronous motor, and magnetically operated mercury switch. The cam rotates at constant speed, usually revolving every 15 sec. As the cam moves, it moves the magnet away from the mercury switch to close it. The cam-shoe arm is positioned by the differential pressure of a venturi tube,

etc., depending on the function being measured. The length of time that the cam-shoe rides on the cam-face determines the time the switch is closed and this time interval varies in direct proportion to the magnitude of the variable being measured. The same proportionate signal which actuates a receiving instrument can also be used to control pumps, valves, and chemical feeders.

The output signal from an electric transmitter can be sent over private wires, telephone circuits, or over multiservice wires, and can be transmitted any distance from a few feet to many miles. By means of a sequencing device (known as a sequence unit transmitter) signals from several transmitters can be sent consecutively over the same pair of wires. Sequencing is not often used in sewage works, but may be used to control remote lift station pumping operations.

Pneumatic transmission is frequently used in sewage works because hydrogen sulfide is usually present to some degree and corrosion of electrical contacts and terminals may be a problem. There are many other reasons for its use. The transmitter contains a specially calibrated cam, positioned by a diaphragm or mercury-well float, and operates and controls a bleeder valve system and bellows unit to produce an output pressure directly proportional to the rate of flow or liquid level being transmitted.

The principal features of pneumatic transmission are absence of wiring from transmitter to receiver, continuous (rather than intermittent) output signal (pressure), extreme sensitivity to pressure change, simplicity, and reasonably trouble-free operation.

21.32 Summation

It is often desirable to add two or more flow rates of individual units to provide, on a single receiving instrument, a total representing the combined rate. This addition is accomplished by a summation unit, either electrical or pneumatic. The electrical summator receives signals from time-impulse transmitters and, by means of proper linkages, positions its own time-impulse transmitter to represent the sum of the individual signals.

The pneumatic summator receives the output pressure from the individual transmitters, adds them together, and by positioning a retransmitter, sends out its own air pressure proportional to the total of the individual pressures, and, therefore, proportional to the total of the individual flows. The output signals or pressures from these summators may be used for metering, control of chemical feeders, proportional pacing of chlorine feeders, sluice gate positioning, and other operations.

21.33 Receivers

Since flow varies as the square root of the head, secondary instruments or receivers are constructed to take the information received and to make necessary mathematical calculations so that the reading will be in the units desired by the operator. This calculation is done in one of two ways: (*a*) the chart or indicator scale is of the square root type, wherein the divisions are spaced according to the square of the units; or (*b*) the receiver has a cam which extracts the square root of the head and converts it to a linear movement, the indicator or chart showing the observation on a linear chart or scale.

Where indicator-recorders are used, the indicator arm may be separate from the chart or it may be attached to the pen arm. Indicator-totalizer combinations have an indicator arm and a counter.

21.34 Flow Ratio Gages

For the proper control and operation of activated sludge plants, the operator must know the relation of air supplied to sewage flow, and the relation of re-

turned sludge to sewage flow or per cent return sludge. These relations can be calculated from observed data, and they also can be determined continuously by flow-ratio gages. For this type operation, pneumatic transmitters, summators, and an anti-log computer are used.

21.35 Conveyor Scale Metering

Many waste treatment plants are equipped with vacuum filters, and conveyor systems are usually part of the installation. A scale mechanism can be incorporated into the conveyor to continuously totalize and indicate the rate of flow of the dewatered sludge.

The mechanism weighs the loaded belt passing over it and at the same time subtracts the weight of the return belt, plus any material adhering to the belt, thus maintaining a constant tare; the results are a true net weight of the sludge cake.

Total weight and rate of flow of the sludge are extremely useful data for determining filter efficiency and for the proper control of incinerators.

21.36 Controls

Meters are extremely useful in providing control of flows, chemical feeding, proportioning, pumping, sampling, and other operations. Control can be accomplished by electrical, pneumatic, or mechanical means.

When using an electrical system, for example, contacts may be preset to operate after a predetermined number of gallons have passed or when the flow reaches a predetermined rate. Timers may be used with proportional sampling systems. Pneumatic systems are often used because the output air pressure from the rate of flow transmitter is continuous, thereby minimizing the time of response of the controlled unit. Straight mechanical control is usually limited to the operation of valves and pumps.

21.4 OPERATION PROBLEMS

Many problems arise in the operation of flow measuring equipment. It is impossible to discuss all that have been reported, but a few of the more common types are worth mentioning.

21.41 Negative Head

Negative head is a condition which may occur in a differential producer if installation is improper. It occurs when the liquid pressure inside either or both mercury wells is less than atmospheric. When this happens, air may enter and become trapped in the pressure lines or wells, thereby causing serious errors in the readings. When the head in a pipeline is insufficient to keep a positive pressure on both wells of the instrument under all conditions, a transmitter at a lower elevation must be used, or float pipes may be used as an alternate to mercury wells, or the secondary instrument may have to be moved to a lower position.

21.42 Foreign Bodies

Foreign bodies often find their way into measuring devices both during construction and during operation. Any foreign body will adversely affect operations of a measuring device. Solids which build up behind or on the edge of weirs and orifices cause errors in measurement. The only remedy for this situation is to use care to prevent the entrance of such bodies and to remove them when they appear.

21.43 Deposits

Deposits on the surfaces of a primary device (as, for example, the deposition of grease or calcium soaps or the growth of slimes on weir and

orifice edges) will cause a change in flow characteristics of the device and measurements will be incorrect. Cleaning is the remedy.

21.44 Wear, Moisture, and Erosion

Wear on transmitter or receiver parts, especially if the wear is on a cam, will cause the apparent measurement to vary from the tare measurement.

Moisture in the receiver may cause wrinkling of the charts. Protection against the elements or some means of keeping the chart dry, as by a light bulb or heating element in the housing, may solve the problem.

Erosion of the walls of a primary device may be caused by the presence of sand and gritty particles in the sewage. Continual wearing away of the lining of the device will change its flow characteristics and cause a decrease in accuracy.

21.45 Pulsating Flow

Pulsating flow is the most difficult flow to measure. This type of flow occurs where reciprocating pumps or lobe-type blowers are used. The differences between these two cases is significant. It is not as difficult to meter a pulsating liquid flow as it is a pulsating gas flow. In the case of air or gas flow, examples can be given where differential meters indicate a considerable flow when the end of the line is closed and there could be no flow. This is caused by a standing wave pattern resonating in the closed pipeline. The effect of a particular pulsation on a differential meter measuring a compressible fluid is impossible to predict, except for the simplest system. If the flow must be measured, it is wise to install a compressor producing a continuous or non-pulsating flow.

Accurate measurement of a pulsating liquid flow with a differential meter is often possible, but depends largely on the form of the pulsations. The principal error in measuring this type of flow comes from the meter sensing an average differential and indicating a flow based on this average. The true average flow, however, depends on the average of the square root of the differential, not the square root of the average differential. The error introduced by this situation often can be calculated and the readings corrected accordingly. Each individual case must be analyzed and equipment designed to handle the problem.

21.46 Maintenance

Continuing accuracy depends on the quality of the maintenance program. Preventive maintenance is the only insurance against costly breakdowns. Good maintenance requires know-how, tools, and spare parts.

34th ANNUAL MEETING

WATER POLLUTION CONTROL FEDERATION

Milwaukee, Wis. *October 8–12, 1961*

Schroeder-Hotel Auditorium

22. SAMPLING OF SEWAGE

22.1 REPRESENTATIVE SAMPLING

Nearly everyone agrees that laboratory analyses have little value or meaning if the material analyzed is not fairly representative of the condition or quality which actually prevails. With sewage, obtaining this representative sample is the most difficult sampling problem.

The greatest obstacle to the collection of a representative sample is the lack of homogeneity of sewage, particularly in its raw state as it arrives at the plant. Accordingly, sampling points must be located where there is good mixing of the material to be sampled, uninfluenced by previous deposits and unrelated side effects. The conscientious operator, therefore, must study his facilities closely to find these points.

Even under the most favorable circumstances, errors or inaccuracies in sampling are usually much greater than those ascribed to laboratory methods. Moreover, costly equipment and careful work in the laboratory are wasted when samples are collected carelessly.

22.11 Reasons for Grab Sampling

Grab samples or single catch samples are taken for the following reasons:

1. Where frequent changes in characteristics and concentrations of certain constituents of the sewage require concurrent changes in plant operational control. For example:

   (*a*) Chlorine demand and chlorine residuals, particularly for disinfection. Maintenance of residual within narrow limits may require frequent adjustments of rate of dosage.

   (*b*) Concentration and settleability of mixed liquor and activated sludge.

2. Where unusual or undesirable constituents or concentrations are observed. For example:

   (*a*) Toxic wastes such as cyanides, chromium, or copper.

   (*b*) Oils and greases.

   (*c*) Strong organic wastes such as milk, cannery, or tanning.

3. Where a condition or operation is of short duration and quite uniform. For example, tests for pH, moisture, and volatility on:

   (*a*) Digester supernatant withdrawal or transfer.

   (*b*) Raw sludge pumped to digester from sludge wells.

   (*c*) Digested sludge going to drying beds.

4. Where a condition or quality remains relatively uniform for daily periods or longer, as for example of sludge at selected points in a digester or Imhoff tank.

5. Where the sample requires immediate analysis by reason of a high degree of instability of the constituent to be analyzed, as for example dissolved oxygen.

22.12 Reasons for Composite Sampling

Composite or integrated samples are collected when a measure of the aver-

age quality or condition in the plant or stream is sought, with sampling covering a period usually no longer than 24 hr. The samples commonly are obtained for routine analyses of solids, BOD, nitrogen, etc. Ideally, a continuous sample should be taken with volumes at all times in proportion to rate of flow. Where this is not practicable, samples taken hourly and composited may give reasonably accurate results. Greater frequency may be required where sudden changes occur with wide variations in composition.

Where samples are collected during a period less than 24 hr, as in small plants, a relationship between the quality found during the shorter period with the daily average should be established. A factor representing this relationship should thereafter be applied to compute daily values.

22.2 SAMPLING EQUIPMENT

22.21 Automatic Sampling Equipment

Some equipment is designed to collect composites in proportion to sewage flow by: (*a*) taking a portion at regular time intervals, with sample size varying with flow, or (*b*) taking uniform portions on a time schedule varying with the total flow. Other equipment is designed to collect uniform portions at regular time intervals.

Automatic sampling offers these advantages:

1. Elimination of human error inherent in manual sampling;
2. Reduction of personnel requirements and costs;
3. Elimination of a routine task which may become an undesirable chore; and
4. Permits more frequent collection of portions than is practicable by manual sampling.

The limitations of mechanical samplings include:

1. Equipment requires considerable maintenance;
2. Close attention is required when sampling raw or partially treated sewage containing solids, some of which may be of large diameter;
3. Equipment is restricted as to size of feed pipe, width of scoop, etc.;
4. Usually, individual portions must be small if very large receiving containers are to be avoided;
5. Daily cleaning of all parts in contact with sewage is mandatory.

22.22 Manual Sampling Equipment

22.221 Dipper:—Long-handled dipper of stainless steel or other corrosion resistant material. The dipper should be cylindrical in shape with a wide-mouth opening (minimum of two inches) and be large enough to contain largest portion to be collected.

22.222 Weighted Bottle:—A weighted device designed to hold a stoppered bottle while it is lowered to desired sampling depth. A cord or wire is attached to the stopper for removal of stopper at desired depth. Very little sewage will be displaced from the bottle while it is being drawn to the surface.

22.223 Hand-Operated Pump:—A tube fixed to the suction of an ordinary "pitcher" pump may be lowered to a

desired point from which a sample is to be collected.

22.224 Cross-Section Sampler:—For stratified solutions, such as sludge in digesters or sludge blankets in settling tanks, a graduated glass or plastic tube or cylinder open at both ends and stoppered may be used. The tube is lowered through the tank with both stoppers removed, cutting a "cross-section" sample. In sampling position, the stoppers are put in place by a lever arrangement.

22.3 SELECTION OF SAMPLING POINT

22.31 Raw Sewage

Samples should be collected preferably after the waste has passed through screening and grit removal facilities. Estimate of screenings and grit can be added to results of laboratory tests to approximate raw sewage.

22.32 Settling Tank Effluent

Samples should be taken at the discharge of the effluent trough or pipe, or in the effluent trough itself, or in the settling tank just ahead of the discharge weir. Preference would normally be in the order indicated. These comments apply equally to primary, intermediate, and final sedimentation.

22.33 Trickling Filter

22.331 Influent:—A wide-mouth jar buried in media below distributor arms will usually suffice.

22.332 Effluent:—A sample may be collected in filter effluent trough, if accessible, or in inlet to secondary settling tank.

22.34 Aeration Tank Mixture

Samples should be collected in locations having as much turbulence as possible, insuring a well-mixed specimen.

22.35 Chlorine Residual

For single-stage chlorination, collect sample at point of discharge of effluent to receiving waters.

22.36 Sand Filter

22.361 Influent:—Collect sample from dosing chamber or at discharge from distributor onto the sand bed.

22.362 Effluent:—Collect sample at discharge of underdrainage system.

22.37 Sludge

22.371 Raw Sludge:—If raw sludge can be drawn from the settling tank hoppers into a well or pit before pumping, it should be mixed, then a representative sample dipped directly from this well. Also, samples may be collected from openings in pipes near the sludge pumps or from the pump itself.

22.372 Return Activated Sludge:—Samples may be collected from:

1. Pump suction well,
2. Pump or adjacent piping, or
3. At point of discharge of return sludge to the primary effluent. Sample point should be located in region of good agitation to insure suspension of solids.

22.373 Supernatant Liquor:—Samples may be collected from sampling cocks provided for this purpose in digester control room or through the digester cover opening using a weighted sampler or cross-section sampler.

22.374 Digested Sludge:—Samples should be taken at point of discharge of digester draw-off pipe to drying beds or drying equipment.

22.4 SAMPLING METHODS AND PROCEDURES

22.41 Below Weirs

Care should be taken in sampling below a weir since deposition of solids in the pool upstream from the weir and floating oils or grease just downstream can cause errors in sampling.

22.42 Sewers and Channels

Care should be taken to avoid skimming the surface (scum and greases), and dragging bottom or sides. A sample collected from the middle third of the cross-section of flow is most desirable.

22.43 Wide Channels

Samples should be collected from the middle third (vertically) of the channel and the point of collection should be rotated across the channel, always taking care to avoid disturbance of the channel sides and to select a point where the velocity is sufficient to prevent settling.

22.44 Deep Sewer Manholes

Care must be taken to prevent extraneous material in the manhole from entering the sample.

22.45 Settling Tanks

An effluent sample taken directly from the tank (see Section 22.32) should be collected just ahead of the outlet weir and below any scum layer.

22.46 Unscreened Sewage

Where it is not practicable to sample raw sewage following screening, a considerable portion of the sewage should be collected in a pail or other large container, well mixed, and then sampled as usual.

22.47 Special Test Sampling Locations

Sometimes samples should be collected from several points in the same tank or channel. For example:

1. In aerators the maximum dissolved oxygen level is likely to be near the outlet and the minimum near the inlet.

2. In final settling tanks, the maximum dissolved oxygen level probably will be near the inlet and the minimum near the outlet.

22.48 Sludge

A sample drawn from a sludge pump represents only the quality and concentration of sludge being pumped at the instant the sample is drawn. Since these characteristics may vary rapidly, portions of sludge samples should be drawn into a pail several times during the sludge-pumping operation. The sludge should be well mixed in the pail before removing a sample for analysis.

Also see Section 22.37.

22.5 SAMPLE VOLUME AND FREQUENCY OF SAMPLING

22.51 Grab Samples

The volume collected should be large enough for the laboratory test to be made plus an additional amount for a second test in case of doubtful results or failure of the first test caused by spillage, equipment breakdown, etc.

The frequency of collection of these samples usually is determined by the specific determination to be made. For instance, samples for chlorine residual tests might be collected hourly, while a grab sample for dissolved oxygen in the receiving stream might be collected only once a day.

22.52 Composite Samples

The composite sample, in addition to reflecting the composition of each portion, should reflect the average composition for the total period of collection. To this end, individual portions are commonly collected in amounts proportionate to the waste flow.

Satisfactory results are also obtained by collecting a portion of uniform size each time a predetermined amount of flow had passed the sampling station. Using this scheme samples are collected more often during high flows and less often during low flows. The necessity for continuous observation of flow meters and the non-uniform schedule of sampling is a disadvantage of this procedure.

The volume of the composite usually varies between one quart and one gallon. Single portions seldom are smaller than 100 ml and preferably not less than 200 ml. Ideally, a composite sample would be a continuously collected sample with volumes at all times in proportion to rates of flow, over a full 24-hr period. Where this is not possible, portions may be collected at frequent intervals, such as one an hour.

22.6 HELPFUL HINTS ON HANDLING SEWAGE SAMPLES

1. Collect enough sample in a suitable container. Error can result from attempting to collect small portions for a composite sample. The sample should be taken from a point in the treatment process where mixing has created a somewhat homogenous condition. The nature of sewage prevents the collection of a relatively small portion that represents the whole. This is particularly true of raw or unsettled sewage. A minimum sample should be at least 100 ml and a sample containing any unusual particles should be rejected.

2. Always mix the sample before removing a portion. If this operation is neglected, the liquid removed will not represent the original. Mixing may be accomplished by shaking, stirring, or other means, depending on the analyses to be conducted and the judgment of the analyst. Careful stirring is suitable for a BOD test, whereas shaking is fine for a solids determination.

3. When removing a measured portion of sample, use appropriate method. For example, if a portion of 50 or 100 ml is desired for a test such as suspended solids, it is better to use the correct-size graduated cylinder or volumetric flask. The sample should be thoroughly mixed and rapidly poured into the measure. It is preferable to miss the exact amount by a small degree rather than to use extreme care in pouring. Extreme care in pouring allows time for the particles in suspension to settle, resulting in error. In a test such as a total solids or suspended solids in sewage, the cylinder or flask can be rinsed with distilled water and the rinsings added to the evaporating dish or crucible without adversely affecting the results.

Smaller portions such as might be used for BOD tests can be measured with a pipette. However, a fine-tipped pipette can cause error by straining out larger particles. The pipette tip (graduated pipette) can be enlarged or cut off. If the opening is sufficiently large, the pipette can be filled by dipping into the container of mixed sample, eliminating the need for using the mouth or a pipette bulb. Only one portion should be pipetted at a time, as the delay in dispensing more than one portion from the same pipette allows the contents to separate in the pipette.

Good judgment is necessary in all measuring operations. If the analyst

realizes the possible causes of error, he can often devise procedures to minimize them.

4. Preserve the sample during any delay before analysis. For routine sewage tests, refrigeration is adequate. The temperature should be less than 50°F. With a thermometer inserted through the stopper of a refrigerated bottle of water, the temperature can be read without the rapid change that results from opening a refrigerator and reading an unprotected thermometer.

This chapter completes the serialization of the Federation Manual of Practice No. 11, "Operation of Sewage Treatment Plants."

The manual will be printed as a separate volume in the coming months. Watch the Journal for further announcements.

Readers have been invited to make critical comments on the contents of the manual. Such comments will be evaluated by the Subcommittee on Operation of Sewage Plants prior to making final corrections.

You are again urged to share your review of the manual with the Subcommittee. Address all correspondence to the Federation office. All comments received by August 15 will be considered by the Subcommittee.

TIPS AND QUIPS

Modern Sewage Treatment

The accompanying photo, taken on the nuclear-powered Polaris Ballistic Missile Submarine USS George Washington, shows waste material being deposited in a specially designed mesh bag which, when weighted with a brick, is fired from the submarine.

We hear rumblings of sending radioactive waste into outer space but wager there are few who ever considered ordinary sewage to be a missile.

Official U. S. Navy Photo

Loading mesh bag with waste and a brick preparatory to firing from USS George Washington.

Sewerage Safety

Other cities can take a lesson from Brooklyn's sewerage safety school. Since 1951 the city has had training facilities consisting of the following:

1. A full-scale model sewer, completely above ground, consisting of 45 ft of 36-in. corrugated steel pipe leading into a brick manhole 8 ft high, complete with sewer stubs, manhole head, and cover.

2. A gas or smoke chamber standing about 6 ft from the manhole of the sewer assembly. It is $8 \times 8 \times 8$ ft in size, built of fire-retarded wood and floored with concrete. An overhead platform, paved with asphalt and surrounded with guard rails, connects the chamber and top of manhole, serving both as a roof for the chamber and a section of simulated roadway in which the manhole is set. A stairway affixed externally to a wall of the gas chamber provides access to the platform. Entrance to the chamber is by a conventional door, and the exit is a ground level escape hatch door deliberately made only 3 ft high.

Brooklyn attributes its excellent safety record largely to the safety training program.

Full details were reported in *American City*, **75**, 1, 69 (Jan. 1960).

Engineers' Attitude

A study by the Professional Engineers Conference Board for Industry in cooperation with the National Society of Professional Engineers about engineers' attitude on professionalism revealed some interesting differences of opinion.

1. Fifty-six per cent of managers felt their companies recognize the professional status of engineers to a "very high" degree, but only 26 per cent of engineers agreed. Fifty-one per cent of the engineers felt their professional status was recognized by companies to only a "moderate" degree.

2. Almost 70 per cent of managers said management shows "genuine respect" for engineers, but only 36 per cent of engineers agreed. Ninety per cent of managers rated engineers among the most valuable employees, but only 52 per cent of engineers felt they are so regarded. The report states that if companies are doing all they say they are many of these programs and policies are not now getting through to engineers.

3. Before interviews were conducted, surveyed companies were analyzed and rated on actual efforts to promote professionalism among engineers. In the high scoring companies, 44 per cent of engineers think management really believes in the professional status of engineers, while only 7 per cent of engineers in the lower scoring companies agree. Fifty-three per cent of engineers in the lower scoring companies said engineers are "sort of a commodity—let go quickly if business is poor," but only 17 per cent of engineers in high scoring companies agreed.

Coffee Break

Approximately half of the tonnage of industrial organic wastes produced in New Jersey consists of coffee grounds.

Sanitary Engineering News

Russian Pollution

Russian newspapers are alarmed at the pollution of Russia's 225,000 miles of rivers, which is killing fish and endangering public health. The northern Donetz River, the "Ruhr of Russia" receives 275 mgd of sugar, chemical, and steel plant wastes. We can think of a number of river systems in the U. S. which would be in much better condition if they individually received only this amount of waste.

Engineers' Job Outlook

If one midwestern school's experience can be considered representative, employment for graduating engineers continues to be bright. A study of 205 companies by Northwestern University revealed that industry expected to hire 6 per cent more engineers but 3.2 per cent fewer non-technical graduates this spring. Engineers' salaries are expected to average $520 a month, compared with $450 for those trained in business specialties.

Last year the typical graduate interested in industry had 5 job interviews with 2.4 job offers.

Engineers' Salaries

A nationwide salary study by the U. S. Bureau of Labor Statistics comparing engineers' salaries in industry and government indicate, as expected, that those in industry fare better economically than do federal employees.

Six levels of industrial engineers were surveyed, starting with a trainee level of professional work typically requiring a college degree. The following table shows those in comparison with the federal GS ratings.

Grade Level	Industry Avg	Government Min	Government Max
Engineer I (GS-5)	$ 6,371	$ 4,345	$ 5,335
Engineer II (GS-7)	7,241	5,355	6,345
Engineer III (GS-9)	8,411	6,435	7,425
Engineer IV (GS-11)	9,868	7,560	8,860
Engineer V (GS-12)	11,620	8,955	10,255
Engineer VI (GS-13)	14,193	10,635	11,935

The full report, BLS Bull. 1286, is available at 35 cents a copy from the Superintendent of Documents, GPO, Washington 25, D. C.

NEWS AND NOTES

People and Events in the Wastewater Field

O. J. Muegge, State Sanitary Engineer of the Wisconsin State Board of Health, received a distinguished service citation from the University of Wisconsin College of Engineering faculty and the university president.

Thomas R. Glenn, Jr. has been appointed Executive Secretary of the American Sanitary Engineering Intersociety Board, Inc., and the office of the Board has been moved to P. O. Box 143, Highland Park, N. J.

Lock Joint Pipe Co., East Orange, N. J., recently acquired Corroplast, Inc., Passaic, N. J., extruder of rigid polyvinyl chloride pipe and other shapes.

John R. Williams is a busy man. In addition to being owner of the consulting engineering firm of Johnson & Williams he is President and founder of the Potomac Bank and Trust Co. in Falls Church, Va., and also is President of the Williamsburg Corporation, which owns the Williamsburg Shopping Center in Fairfax County, Va.

Murray A. Wilson of Wilson & Co., Salina, Kans., has been elected President of the National Society of Professional Engineers.

Charles V. Costello, Binghamton, N. Y., is now in Liberia in an instructional water treatment program.

Fred E. Lange is now Director of Technical Services, Municipality of Metropolitan Seattle (Washington). He formerly was Engineer and Manager of the Vallejo (California) Sanitation and Flood Control District.

Rolf Eliassen will join the Stanford University faculty as Professor of Civil Engineering in the fall. He now is Acting Head of the Department of Civil and Sanitary Engineering at Massachusetts Institute of Technology, where he has been since 1949.

Abel Wolman, Professor of Sanitary Engineering at Johns Hopkins University in Baltimore, Md., and **Thorndike Saville,** consulting engineer and active on the staff of the University of Florida in Gainesville, were among the four named honorary members of ASCE at its recent convention.

Frank S. Taylor recently was appointed Superintendent and Engineer of the Oklahoma City Water Department, succeeding **Morrison B. Cunningham,** who had served the City for 41 years. Mr. Taylor received the Bedell Award in 1950.

Atlanta, Ga., recently dedicated its new South River Water Pollution Control Plant.

Ray V. Tilly has retired from the firm of Crawford, Murphy & Tilly, Springfield, Ill. **Charles L. Ritchie** has been named as an associate of the firm. He formerly was with the Illinois State Department of Public Health.

Claude K. Rice, Analytical and Testing Section Coordinator for the Gulf Oil Corporation's Philadelphia Refinery Technology Laboratory, recently received ASTM's Max Hecht Award, given annually for outstanding work in the field of industrial water.

The Penn Instruments Division of Burgess-Manning Co. has become a part of the Penn Meter Co., Philadelphia, a newly formed corporation.

A. D. Caster has been elected President of the Technical and Scientific Societies Council in Cincinnati and Vice-President of the Ohio State Society of Professional Engineers.

M. S. Campbell, Chief Engineer of the H. D. Fowler Co., Seattle, has been appointed to the Washington State Board of Health.

A. M. Buswell has retired from his duties as Research Professor at the University of Florida and is devoting full time to consulting activities.

Harris Seidel was in Taiwan recently on a study for the World Bank.

Franklin L. Sommer has rejoined the **Simplex Valve and Meter Co.,** Lancaster, Pa., in the capacity of District Sales Manager for the Philadelphia area.

REVIEWS AND ABSTRACTS

The Treatment and Disposal of Sewage Sludge. By W. F. Brown. *Jour. Inst. Munic. Engrs.*, **87**, 65 (1960).

The author surveys the methods used for the treatment and satisfactory disposal of sludge from sewage treatment plants. A sludge treatment process must be economical, pathogenically safe, nuisance-free, and should be salable.

Digestion, usually mesophilic, can reduce the organic content of sludge by up to 60 per cent and produce 1 cu ft/cap of a gas mixture of CO_2 and CH_4 with a calorific value of 650 to 700 Btu/cu ft. It was found in Britain that dehydration of sludge was becoming more difficult due to the increased protein content—an indicator of a rising standard of living.

Natural drying of sludge on underdrained beds tended to be a slow process during English winters and storage in lagoons or provision of extra bed space was often necessary.

Chemical conditioning with salts such as ferric chloride, aluminum, chlorohydrate, etc., was necessary before mechanical methods of dewatering. This conditioning also aided natural sludge drying.

Pressure filtration, a messy, batch process, had been replaced by vacuum filtration which worked well for all sludges (for activated sludge only when well nitrified). The blinding of sludge on the filter cloth had resulted in the use in the U.S.A. of coil springs or nylon threads as filter media, but these media allowed appreciable amounts of fine solids to pass through into the filtrate.

Sludge conditioning by heating to 360°F is thought to give a highly polluting liquor and odors, while sludge freezing in conjunction with chemical conditioners as tested on laboratory and pilot scale can give yields of up to 100 times that obtained by using the chemical conditioners alone. Refrigeration power costs would be high.

Heat drying systems are the rotary kiln type and the flash drying system which produces ½-in. diameter sludge pellets. Capital and maintenance costs amount to £15 to 20/ton of which 50 per cent can be recovered by sale of dried sludge. The simplest method of disposal of wet sludge is by trenching or lagooning; digested sludge can be piped wet, or taken by tanker to nearby sites for fertilizer for animal fodder crops. Landfill with sludge may give rise to groundwater pollution and possible danger of spontaneous combustion. One third of the sludge from England and Wales is dumped at sea.

D. Jenkins

Hydraulic and Sediment Survey of the Estuary of the River Tyne. Report for the year July 1959 to June 1960. By E. Miller, J. H. Allen, and D. G. Hall. Bull. 20, Dept. Civil Engr., Univ. Durham, King's College, Newcastle upon Tyne.

Early in 1959 the Hydraulics and Hydrology Section of the Department of Civil Engineering, University of Durham, began a tidal and sediment survey of the estuary of the River Tyne. Later a Committee of Tyneside local authorities, which had been formed to examine the possibility of modern sewage disposal in the area, provided additional financial assistance to enable the survey work to be expedited. This Bulletin is the report of the first full year's work.

Some of the preliminary general conclusions are as follows:

1. During an average tide the volume of water in the estuary at high water is about 1½ times that remaining at low water.

2. The average freshwater flow entering above the tidal portion of the estuary is about 1,500 cfs, ranging from less than 200 to over 10,000 cfs. (The corresponding volume of sewage entering the estuary is 65 cfs.)

Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Water Pollution Control Federation, 4435 Wisconsin Ave., Washington 16, D. C.

3. The average dilution with tidal sea water could be about 300, but mixing is far from complete owing to saline stratification in the estuary. This stratification, fortunately, is most marked at times of flood flow from the freshwater reaches.

4. The net downstream movement of a complete cross section of river water was found to be between 0.4 and 0.9 mile in a complete tidal cycle. This is, of course, greatly affected by stratification. The surface waters can move three times as far as the average, while the bottom waters move predominantly upstream.

5. On the ebb tide the concentration of suspended solids is more or less uniform throughout the river water, averaging 15 to 20 mg/l. On the flood tide, however, the much higher bottom velocities bring the bottom silts into suspension and move quantities of particles upstream; in one case, for example, it was calculated that 30 per cent more solid material was carried upstream with the flood than was carried downstream with the ebb tide.

6. The river brings down into the tidal estuary about 15,000 tons of suspended solids (dry weight) per year. Maintenance dredging in the river is concentrated in three zones. The organic content of the river muds increases downstream until 2½ miles short of the river-mouth piers, where it starts to decrease, reaching zero at the piers.

7. Phenol and cyanide concentrations were measured and were low.

8. The estuary is deficient in dissolved oxygen in the summer. (It is interesting to observe that this should be expected from the work of the Royal Commission on Sewage Disposal (1898–1912) which, although it was not concerned with estuaries, recommended that:

(a) Where available dilution is 150 to 300, the suspended solids must be reduced to 60 mg/l before discharge —there is no BOD requirement; this calls for chemical precipitation.

(b) Where available dilution is 300 to 500, the suspended solids must be reduced to 150 mg/l; this calls for plain settlement.

The Tyneside sewage receives no treatment whatever before discharge.)

PETER C. G. ISAAC

BOOKS, REPORTS, PAMPHLETS

Part 1, Determination of the Quantity of Oily Substances on Beaches and in Nearshore Waters; and Part 2, Characterization of Coastal Oil Pollution by Submarine Seeps. PART 1 BY THE SANITARY ENGINEERING RESEARCH LABORATORY, UNIVERSITY OF CALIFORNIA; PART 2 BY THE ROBERT A. TAFT SANITARY ENGINEERING CENTER, UNITED STATES PUBLIC HEALTH SERVICE. State Water Pollution Control Board, Sacramento, Calif. Publ. No. 21. 62 pp. Price, $1.50 (1959).

A report of investigations of the oil pollution problem from coastal oil fields encountered in offshore California waters.

An Industrial Waste Guide to the Cotton Textile Industry. BY THE NATIONAL STREAM SANITATION COMMITTEE OF THE AMERICAN ASSOCIATION OF TEXTILE CHEMISTS AND COLORISTS IN COOPERATION WITH THE NATIONAL TECHNICAL TASK COMMITTEE ON INDUSTRIAL WASTES. U. S. Dept. of Health, Education, and Welfare, Public Health Service, Washington, D. C., Publ. No. 677. 23 pp. Price, 25¢ (1959).

The fifth in this series of industrial waste guides. Defines the textile industry waste problem and describes remedial measures and treatment methods.

A Simplification of Textile Waste Survey and Treatment. BY JOSEPH W. MASSELLI, NICHOLAS W. MASSELLI, AND M. GILBERT BURFORD. New England Interstate Water Pollution Control Commission, Boston, Mass. 68 pp. (1959).

An extensive research report of cotton, wool, and synthetic fiber waste problems. Basic aim of report is to bring together data to simplify the solution of waste problems. Simplification of treatment methods is also discussed.

A Digest of State Air Pollution Laws. BY SAMUEL M. ROGERS AND SIDNEY EDELMAN. U. S. Dept. of Health, Education, and Welfare, Public Health Service, Washington, D. C., Publ. No. 711. 117 pp. Price, 75¢ (1959).

INTERNATIONAL RESEARCH CONFERENCE PLANNED FOR 1962

The Water Pollution Control Federation is principal U. S. sponsor for an International Conference on Water Pollution Research expected to be held in or near London during September 1962.

The program of the Conference will be generally divided into three symposia, expected to continue through one calendar week. The titles of these symposia and their chairmen are as follows: (*a*) Self Purification of Fresh Water Streams and the Effects of Pollution on Fisheries, Dr. B. A. Southgate, Director, Water Pollution Research Laboratory, Stevenage, England; (*b*) Treatment of Sewage and Industrial Wastes, Professor W. W. Eckenfelder, Jr., Professor of Sanitary Engineering, Manhattan College, New York, N. Y.; and (*c*) Effects of Pollution on the Marine Environment, Dr. E. A. Pearson, Professor of Sanitary Engineering, University of California, Berkeley, Calif.

Each symposium will include a maximum of 16 papers. All papers will be preprinted and distributed to preregistrants for the Conference. Written discussion will be invited for presentation at the meeting and publication in the proceedings of the meeting.

There has been an increased emphasis on water pollution research both in the United States and abroad. This research has been directed toward a better understanding of the effects of wastes on fresh-water streams and the marine environment and improved efficiency and economy in waste treatment methods. The interchange of research methods and results between the United States and the rest of the world has been limited because of publication and language barriers. The proposed International Conference on Water Pollution Research is designed to encourage research specialists to exchange ideas with other leading research investigators. This Conference is the only forum devoted to this particular purpose.

The invited European sponsors include two Federation Member Associations, the Institute of Sewage Purification (British) and Abwassertechnische Vereinigung (German). Others include the River Boards Association, the Scottish River Purification Boards, Federated British Industries, all of Great Britain, the World Health Organization, and the Organization for Economic Cooperation and Development in Paris.

Invitations have been extended to potential authors to submit abstracts of papers describing current research work. The final program will be made up of papers selected by the symposia committee chairmen. Steering committee chairmen for various areas participating are as follows: for the American continent and Japan, Professor W. W. Eckenfelder, Jr.; for the British Commonwealth, Dr. B. A. Southgate; for Europe, Professor E. Leclerc, Belgium Center for Study of Water, who has also been invited to serve as President of the Conference; and, for the Soviet Union, Professor C. M. Drachev, A. N. Sysin Institute of General and Social Hygiene, USSR.

If enough are interested it may be possible to obtain economically attractive charter air travel. Conference participants will have the opportunity to inspect noteworthy waste treatment works and research facilities both in England and on the continent. Please mark the anticipated dates of September 3–7, 1962, as the most likely week for this important International Conference.

VAREC GAS BURNER

"A CURTAIN OF FLAME" INSURES POSITIVE IGNITION OF WASTE GAS

Varec engineers designed a double orifice in the pilot flame ring (A). The ring encircles the waste gas nozzle (B)... forms an actual "curtain of flame" that all waste gas must pass through... and which positively ignites the gas.

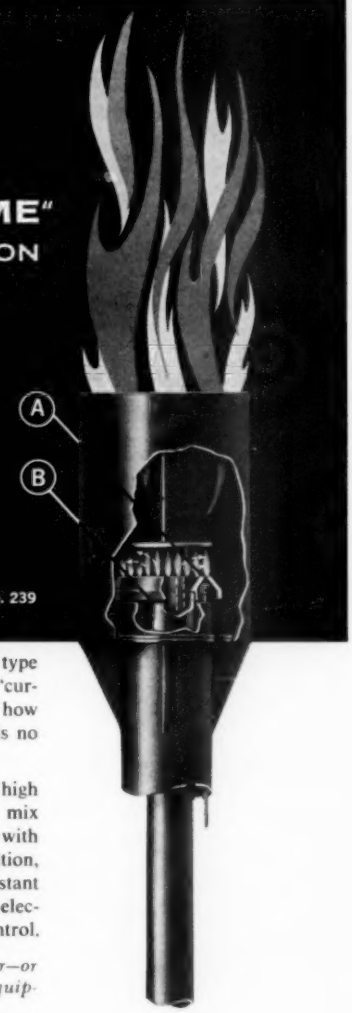

FIG. NO. 239

Varec eliminates ignition problems with its new flare type Fig. No. 239 Waste Gas Burner. The burner's unique "curtain of flame" provides dependable ignition no matter how variable the flow of gas through the burner. There is no loss of pilot flame due to down draft.

Other outstanding features of the new unit include its high burning capacity... an adjustable shutter on the air mix chamber that regulates draft... a high pedestal, packed with insulation to prevent freezing... and rugged construction, with all parts made of steel, stainless steel or heat-resistant cast iron. For critical service, sensing and ignition electrodes are available for remote or automatic pilot control.

For full information on the Varec Waste Gas Burner—or Varec's complete line of advanced design gas control equipment, write for Catalog S-4, Dept. JWP-1222-6.

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WATER POLLUTION CONTROL PRODUCT GUIDE

This list of products and services is offered as an information aid. The list was derived by solicitation from those firms listed. The JOURNAL will make every effort to keep this list current with the help of Associate Members and advertisers. All Associate Members and all advertisers for the past year are included. Many of the services and products are advertised in this issue. For an alphabetical listing see Index to Advertisers in back of JOURNAL.

Aerators (*also see* Diffusers, Air)
Alpha Ltd. (Switzerland)
American Well Works
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Graver Water Conditioning Co.
Infilco Inc.
Link-Belt Co.
Pacific Flush Tank Co.
Penberthy Mfg. Co., Div. of Buffalo-Eclipse Corp.
Permutit Co., Div. of Pfaudler Permutit Inc.
Smith & Loveless
Walker Process Equipment Inc.
Wemco Div., Western Machinery Co.
Yeomans Brothers Co.
Zimmer & Francescon

Agitators
Link-Belt Co.

Air Cleaning Equipment
Westinghouse Electric Corp.

Air Compressors (*also see* Blowers, Compressors, and Fans)
Chicago Pump Co.
Fairbanks, Morse & Co.
Komline-Sanderson Engr. Corp.
Worthington Corp.
Yeomans Brothers Co.

Air Diffusers (*see* Diffusers, Air)

Asbestos Cement Pipe Products
Filtration Equipment Corp.
Industrial Materials Co.
Johns-Manville Sales Corp.
Keasbey & Mattison Co.

Ash Handling Equipment
Link-Belt Co.

Bearings
Link-Belt Co.

Bins, Storage (*see* Tanks)

Biologists (*see* Professional Services, elsewhere in this issue)

Blowers (*also see* Air Compressors, Compressors, and Fans)
Chicago Pump Co.
Roots-Connersville Blower, Div. of Dresser Industries Inc.
Sutorbilt Corp.
Yeomans Brothers Co.
Zimmer & Francescon

Boilers
Combustion Engineering, Inc.

Building Maintenance Equipment and Supplies
Homestead Valve Mfg. Co.

Cast Iron Pipe Products
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
Industrial Materials Co.
U. S. Pipe & Foundry Co.
R. D. Wood Co.

Cement (*see* Concrete)

Centrifuging Equipment
Bird Machine Co.
Permutit Co., Div. of Pfaudler Permutit Inc.

Chains
Chain Belt Co.
Link-Belt Co.
Webster Mfg., Inc.

Chemical Feed Equipment
Builders-Providence Div., B-I-F Industries
Eimco Corp.
Fischer & Porter Co.
Graver Water Conditioning Co.
Infilco Inc.
Jeffrey Mfg. Co.
Komline-Sanderson Engr. Corp.
Link-Belt Co.
Omega Div., B-I-F Industries
Permutit Co., Div. of Pfaudler Permutit Inc.
Proportioneers Div., B-I-F Industries
Wallace & Tiernan Inc.

Chemicals
Dow Chemical Co.
Fisher Scientific Co.
General Chemical Div., Allied Chemical Corp.
Glenn Chemical Co.
Hach Co.
Tennessee Corp.

Chemists (*see* Professional Services, elsewhere in this issue)

Chlorination Equipment
Builders-Providence Div., B-I-F Industries
Everson Mfg. Corp.
Fischer & Porter Co.
Graver Water Conditioning Co.
Wallace & Tiernan Inc.
Zimmer & Francescon

Clarifier Equipment (*also see* Sedimentation Equipment)
Alpha Ltd. (Switzerland)
American Well Works
Ralph B. Carter Co.
Chain Belt Co.
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Graver Water Conditioning Co.
Hardinge Co., Inc.
Infilco Inc.
Jeffrey Mfg. Co.
Komline-Sanderson Engr. Corp.
Lakeside Engineering Corp.
Link-Belt Co.
Permutit Co., Div. of Pfaudler Permutit Co.
Walker Process Equipment Inc.
Yeomans Brothers Co.
Zimmer & Francescon

Clay Pipe Products
Industrial Materials Co.
National Clay Pipe Mfrs., Inc.
National Sewer Pipe Ltd. (Canada)
Robinson Clay Product Co.

Coatings and Linings (Pipe and Tank)
Amercoat Corp.
Centriline Corp.
Corrosion Control Co., Inc.
Inertol Co., Inc.
Koppers Co., Inc.
National Water Main Cleaning Co.
Perry-Austen Mfg. Co.
Stebbins Engr. & Mfg. Co.

Comminutors (*also see* Shredders and Grinders)
Alpha Ltd. (Switzerland)
American Well Works
Chicago Pump Co.
Dorr-Oliver Inc.
Gruendler Crusher & Pulverizer Co.
Infilco Inc.
Jeffrey Mfg. Co.
Smith & Loveless
Walker Process Equipment Inc.
Worthington Corp.

Compressors
Chicago Pump Co.
Fairbanks, Morse & Co.
Komline-Sanderson Engr. Corp.
Roots-Connersville Blower, Div. of Dresser Industries Inc.
Worthington Corp.
Yeomans Brothers Co.

Computers
Minneapolis-Honeywell Regulator Co., Brown Instruments Div.

Concentrators (*see* Sludge Concentrators)

Concrete
Portland Cement Assn.

Concrete Pipe Products
American Concrete Pressure Pipe Assn.
American-Marietta Co.
Gray Concrete Pipe Co., Inc.
Industrial Materials Co.
Lock Joint Pipe Co.
National Sewer Pipe Ltd. (Canada)
Portland Cement Assn.
Price Brothers Co.

Construction Equipment
Chain Belt Co.
Eimco Corp.
Worthington Corp.

Turbo-Compressors—The sale of Spencer turbo-compressors for sanitary engineering applications is being handled exclusively by Walker Process Equipment Inc., Aurora, Ill. Bulletins and other technical literature are available for distribution.

Ultrasonic Liquid-Level Controller—The explosion-proof stainless steel probe of the Sonoswitch is actuated when a liquid touches it. The unit is reported to have a repeatability of several thousandths of an inch and is not affected by film or scale buildup—Powertron Ultrasonics Corporation, Patterson Place, Roosevelt Field, Garden City, N. Y.

Liquid-level controller

Straightline Sludge Collectors—Complete engineering data on straightline sludge collectors are given in an interesting 28-page bulletin replete with pictures and diagrams. Book 2746 is available from your nearest Link-Belt office.

Jet Cleaner—A 4-page bulletin describes the installation and operating and maintenance procedures for a venturi-type injector assembly which combines steam with water and detergent to form a powerful discharge stream. —Bulletin 446, Sellers Injector Corporation, 1600 Hamilton St., Philadelphia 30, Pa.

Portable Ventilator—A new line of portable ventilators for exhausting fumes or circulating air where permanent installations are impractical has been introduced by the Propellair Division, Robbins and Myers, Inc., Springfield, Ohio. The units (see picture) combine a portable fan with lengths of flexible duct, ideal for supplying emergency air to personnel working in cramped spaces.

Zimmermann Process—Operation of the Zimmermann Process, a method of burning sewage sludge in its aqueous state without flame, is described in a 20-page publication. A flow chart, conversion chart, equipment and operating results, and design data are among the items included in the booklet.—Zimmermann Process Division, Sterling Drug Co., Inc., 1450 Broadway, New York 18.

High-Capacity Trickling Filter—Prefabricated filters of aluminum, based on the development work of William T. Ingram, are being manufac-

(*Continued on page 330a*)

Controls (*also see* Instruments, Recording and Control)
Builders-Providence Div., B-I-F Industries
Burgess-Manning Co., Penn Instruments Div.
Chicago Pump Co.
Fischer & Porter Co.
Foxboro Co.
General Electric Co.
Homestead Valve & Meter Co.
Infilco Inc.
Minneapolis-Honeywell Regulator Co., Brown Instruments Div.
Ohmart Corp.
Permutit Co., Div. of Pfaudler Permutit Co. Inc.
Rockwell Mfg. Co.
Wallace & Tiernan Inc.
Westinghouse Electric Corp.
Worthington Corp.

Conveyors
American Well Works
Chain Belt Co.
Chicago Pump Co.
Jeffrey Mfg. Co.
Link-Belt Co.
Stuart Corp.
Webster Mfg., Inc.

Corrosion Protection
Amercoat Corp.
Chicago Pump Co.
Corrosion Control Co., Inc.
Inertol Co., Inc.
Johns-Manville Sales Corp.
Koppers Co., Inc.
Perry-Austen Mfg. Co.
A. O. Smith Corp.
Stebbins Engr. & Mfg. Co.
Wallace & Tiernan Inc.

Couplings
Link-Belt Co.

Diffusers, Air (*also see* Aerators)
Alpha Ltd. (Switzerland)
American Well Works
Carborundum Co.
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Infilco Inc.
Lakeside Engineering Corp.
Link-Belt Co.
Pacific Flush Tank Co.
Penberthy Mfg. Co., Div. of Buffalo-Eclipse Corp.
Walker Process Equipment Inc.
Wemco Div., Western Machinery Co.
Zimmer & Francescon

Diffusers, Gas (*also see* Aerators)
American Well Works
Carborundum Co.
Chicago Pump Co.
Eimco Corp.
Infilco Inc.
Walker Process Equipment Inc.
Yeomans Brothers Co.

Digestion Tank Equipment
Alpha Ltd. (Switzerland)
American Well Works
Ralph B. Carter Co.
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Gorman-Rupp Co.
Hardinge Co., Inc.
Infilco Inc.
Jeffrey Mfg. Co.
Lakeside Engineering Corp.
Link-Belt Co.
Pacific Flush Tank Co.
A. O. Smith Corp.
Smith & Loveless
Vapor Recovery Systems Co.
Walker Process Equipment Inc.
Yeomans Brothers Co.
Zimmer & Francescon

Distributors, Rotary
Alpha Ltd. (Switzerland)
American Well Works
Ralph B. Carter Co.
Dorr-Oliver Inc.
Eimco Corp.
Infilco Inc.
Lakeside Engineering Corp.
Link-Belt Co.
Pacific Flush Tank Co.
Smith & Loveless
Walker Process Equipment Inc.
Yeomans Brothers Co.
Zimmer & Francescon

Dryers
Alpha Ltd. (Switzerland)
Combustion Engineering, Inc.
Eimco Corp.
Hardinge Co., Inc.
Komline-Sanderson Engr. Corp.
Link-Belt Co.
Nichols Engr. & Research Corp.
Stuart Corp.

Ejectors
Komline-Sanderson Engr. Corp.
Smith & Loveless
Tex-Vit Mfg. Co.
Yeomans Brothers Co.

Engineers (*see* Professional Services, elsewhere in this issue)

Engines (Sludge Gas and Petroleum Fuels)
Fairbanks, Morse & Co.
Waukesha Motor Co.
Worthington Corp.

Fans (*also see* Air Compressors, Blowers, and Compressors)
Chicago Pump Co.
Lakeside Engineering Corp.
Westinghouse Electric Corp.

Filter Equipment, Trickling
Alpha Ltd. (Switzerland)
American Well Works
Ralph B. Carter Co.
Dorr-Oliver Inc.
Dow Chemical Co.
Eimco Corp.
Filtration Equipment Corp.
Industrial Materials Co.
Infilco Inc.
Keasbey & Mattison Co.
Komline-Sanderson Engr. Corp.
Lakeside Engineering Corp.
Nichols Engr. & Research Corp.
Pacific Flush Tank Co.
Smith & Loveless
Trickling Filter Floor Inst.
Walker Process Equipment Inc.
Yeomans Brothers Co.
Zimmer & Francescon

Filter Materials
Carborundum Co.
Filtration Equipment Corp.
Glenn Chemical Co.
Graver Water Conditioning Co.
Industrial Materials Co.
Johns-Manville Sales Corp.

Filters, Diatomaceous Earth
Graver Water Conditioning Co.
Yeomans Brothers Co.

Filters, Vacuum (*also see* Vacuum Filters)
Bird Machine Co.
Dorr-Oliver Inc.
Eimco Corp.
Proportioneers Div., B-I-F Industries

Flocculating Equipment
Alpha Ltd. (Switzerland)
American Well Works
Ralph B. Carter Co.
Chain Belt Co.
Dorr-Oliver Inc.
Eimco Corp.
Graver Water Conditioning Co.
Hardinge Co., Inc.
Infilco Inc.
Jeffrey Mfg. Co.
Lakeside Engineering Corp.
Link-Belt Co.
Permutit Co., Div. of Pfaudler Permutit Inc.
Stuart Corp.
Walker Process Equipment Inc.
Webster Mfg., Inc.
Zimmer & Francescon

Flotation Equipment
Chain Belt Co.
Dorr-Oliver Inc.
Eimco Corp.
Graver Water Conditioning Co.
Komline-Sanderson Engr. Corp.
Yeomans Brothers Co.

Flow Measurement
Burgess-Manning Co., Penn Instruments Div.
Filtration Equipment Corp.
F. B. Leopold Co., Inc.

Gas Control Equipment
Alpha Ltd. (Switzerland)
Burgess-Manning Co., Penn Instruments Div.
Ralph B. Carter Co.
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Foxboro Co.
Homestead Valve Mfg. Co.
Pacific Flush Tank Co.
Rockwell Mfg. Co.
Vapor Recovery Systems Co.
Walker Process Equipment Inc.
Zimmer & Francescon

Gas Diffusers (*see* Diffusers, Gas)

Gas Holders, Boilers, and Appurtenances
Ralph B. Carter Co.
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Johns-Manville Sales Corp.
Walker Process Equipment Inc.

Gaskets
Johns-Manville Sales Corp.
Keasbey & Mattison Co.

Gates
Armco Drainage & Metal Products, Inc.
Filtration Equipment Corp.
Industrial Materials Co.
Snow Gates & Valves, Inc.
Webster Mfg., Inc.

Generators
Fairbanks, Morse & Co.
General Electric Co.
Westinghouse Electric Corp.
Worthington Corp.

Grinders (*also see* Shredders and Grinders)
Alpha Ltd. (Switzerland)
American Well Works
Chain Belt Co.
Dorr-Oliver Inc.
Gruendler Crusher & Pulverizer Co.
Jeffrey Mfg. Co.
Yeomans Brothers Co.

Grit Collection and Conditioning Equipment
Alpha Ltd. (Switzerland)
American Well Works
Chain Belt Co.
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Infilco Inc.
Jeffrey Mfg. Co.
Link-Belt Co.
Stuart Corp.
Walker Process Equipment Inc.
Webster Mfg., Inc.
Zimmer & Francescon

PROCEEDINGS OF MEMBER ASSOCIATIONS

GEORGIA WATER AND SEWAGE ASSOCIATION

The Georgia Water and Sewage Association held its Annual Meeting in conjunction with the 29th Annual Georgia Water and Sewage School, Sept. 7–9, 1960. The meeting was held at the Georgia Institute of Technology, Atlanta. The total registration was more than 200, including the ladies.

The Industrial Waste Forum was held on Sept. 8.

Mark D. Hollis, WPCF President, represented the Federation at the meeting, and spoke on "The Water and Sewage Works Man in America's Future," at the Sept. 7 session.

At the Annual Banquet, C. E. Drummond, Jr., of Wiedeman and Singleton, presented the Bedell Award for extraordinary service to the Association to Marion B. Nixon, Assistant Chief of Construction, Atlanta. The Hatfield Award for outstanding treatment plant operation and management went to Leonard E. Waller, Superintendent, South River Sewage Treatment Plant, Atlanta.

Among the outstanding papers presented were:

"Challenges of Industrialization," by Kenneth C. Wagner, Head, Industrial Development Branch, Georgia Institute of Technology, Atlanta.

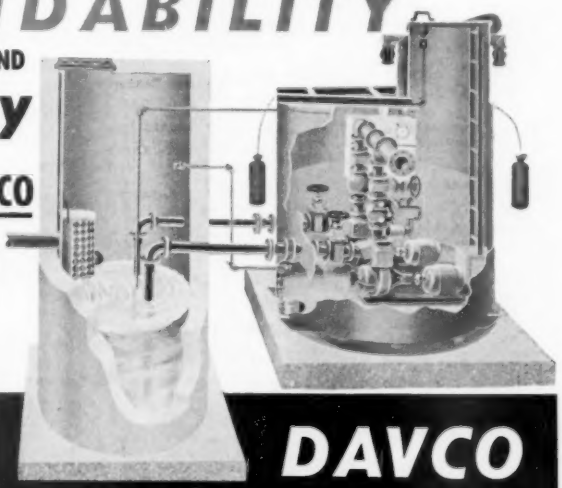
"Industrialization in Georgia," by Walter T. Cates, Executive Vice-Presi-

(*Continued on page 323a*)

DEPENDABILITY AND Economy

DAVCO

BELOW GROUND SELF-PRIMING PUMP STATION



- FLEXIBLE BULKHEAD SEALS
- TIME TESTED CONTROLS SYSTEM
- POSITIVE HIGH LIFT SELF-PRIMING PUMPS
- LIFELONG EXTERIOR PROTECTION

DAVCO CORPORATION
P. O. BOX 270 • TELEPHONE CA 6-6458
THOMASVILLE, GEORGIA

Grounds Maintenance Equipment and Supplies
Homestead Valve Mfg. Co.

Heating Equipment for Digesters and Buildings
Alpha Ltd. (Switzerland)
Ralph B. Carter Co.
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
General Electric Co.
Infilco Inc.
Link-Belt Co.
Pacific Flush Tank Co.
Walker Process Equipment Inc.

Incinerators
Combustion Engineering, Inc.
Nichols Engr. & Research Corp.
Walker Process Equipment Inc.
Zimmermann Process Div. of Sterling Drug Inc.

Insect Control
Glenn Chemical Co.

Inspection, Sewers
Centriline Corp.
National Water Main Cleaning Co.

Instruments, Recording and Control (*also see* Controls and Recorders)
Builders-Providence Div., B-I-F Industries
Burgess-Manning Co., Penn Instruments Div.
Fischer & Porter Co.
Fisher Scientific Co.
Foxboro Co.
General Electric Co.
Hach Co.
Infilco Inc.
Minneapolis-Honeywell Regulator Co., Brown Instruments Div.
Ohmart Corp.
Rockwell Mfg. Co.
Wallace & Tiernan Inc.
Westinghouse Electric Corp.

Ion-Exchange Equipment
Permutit Co., Div. of Pfaudler Permutit Inc.
A. O. Smith Corp.

Jointing Materials
American Concrete Pressure Pipe Assn.
Gray Concrete Pipe Co., Inc.
Keasbey & Mattison Co.
National Clay Pipe Mfrs., Inc.
National Sewer Pipe Ltd. (Canada)
Perry-Austen Mfg. Co.
Robinson Clay Product Co.
Stebbins Engr. & Mfg. Co.

Joints, Mechanical
American Cast Iron Pipe Co.
Johns-Manville Sales Corp.
National Sewer Pipe Ltd. (Canada)
Robinson Clay Product Co.
Smith-Blair, Inc.
U. S. Pipe & Foundry Co.

Laboratory Equipment and Supplies
Filtration Equipment Corp.
Fisher Scientific Co.
General Chemical Div., Allied Chemical Corp.
Hach Co.
Stuart Corp.

Lift Stations
Davco Corp.
Smith & Loveless
Tex-Vit Mfg. Co.
Yeomans Brothers Co.

Lighting Fixtures
General Electric Co.
Westinghouse Electric Corp.

Lubricants
Homestead Valve Mfg. Co.
Johns-Manville Sales Corp.

Manhole and Inlet Castings
American-Marietta Co.
Vapor Recovery Systems Co.

Masonry Building Materials
American-Marietta Co.
Portland Cement Assn.
Price Brothers Co.

Meter Boxes
Johns-Manville Sales Corp.

Meters (Sewage, Sludge, Water, Air, and Gas)
Builders-Providence Div., B-I-F Industries
Burgess-Manning Co., Penn Instruments Div.
Ralph B. Carter Co.
Filtration Equipment Corp.
Foxboro Co.
Infilco Inc.
Minneapolis-Honeywell Regulator Co., Brown Instruments Div.
Rockwell Mfg. Co.
Roots-Connersville Blower, Div. of Dresser Industries Inc.
Simplex Valve and Meter Co.
Worthington Corp.

Mixing Devices
Alpha Ltd. (Switzerland)
American Well Works
Ralph B. Carter Co.
Chain Belt Co.
Dorr-Oliver Inc.
Eimco Corp.
Infilco Inc.
Jeffrey Mfg. Co.
Walker Process Equipment Inc.
Wemco Div., Western Machinery Co.

Motors
Chicago Pump Co.
Fairbanks, Morse & Co.
General Electric Co.
Link-Belt Co.
A. O. Smith Corp.
Westinghouse Electric Corp.
Worthington Corp.

Odor Control Materials
Airkem, Inc.
Tennessee Corp.
Wallace & Tiernan Inc.

Odor Counteractants
Airkem Inc.

Package Treatment
Chain Belt Co.
Chicago Pump Co.
Dorr-Oliver Inc.
Infilco Inc.
Municipal Service Co.
Smith & Loveless
Walker Process Equipment Inc.
Yeomans Brothers Co.

Packing
Johns-Manville Sales Corp.
Keasbey & Mattison Co.

Paints and Protective Coatings
Amercoat Corp.
Inertol Co., Inc.
Koppers Co., Inc.
Perry-Austen Mfg. Co.
Smith & Loveless
Stebbins Engr. & Mfg. Co.

Pipe, Asbestos Cement
Industrial Materials Co.
Johns-Manville Sales Corp.
Keasbey & Mattison Co.

Pipe, Cast Iron
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
Griffin Pipe Div., Griffin Wheel Co.
Industrial Materials Co.
U. S. Pipe & Foundry Co.
R. D. Wood Co.

Pipe, Clay
Industrial Materials Co.
National Clay Pipe Mfrs., Inc.
National Sewer Pipe Ltd. (Canada)
Robinson Clay Product Co.

Pipe Cleaning
Centriline Corp.
Flexible Inc.
Homestead Valve Mfg. Co.
National Water Main Cleaning Co.
W. H. Stewart, Inc.

Pipe Coatings and Linings
Amercoat Corp.
American Pipe & Construction Co.
Centriline Corp.
Koppers Co., Inc.
National Water Main Cleaning Co.
Perry-Austen Mfg. Co.
Stebbins Engr. & Mfg. Co.

Pipe, Concrete
American Concrete Pressure Pipe Assn.
American-Marietta Co.
American Pipe & Construction Co.
Gray Concrete Pipe Co., Inc.
Lock Joint Pipe Co.
National Sewer Pipe Ltd. (Canada)
Portland Cement Assn.
Price Brothers Co.

Pipe, Fiber
Sonoco Products Co.

Pipe Fittings
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
Griffin Pipe Div., Griffin Wheel Co.
Keasbey & Mattison Co.
National Sewer Pipe Ltd. (Canada)
Price Brothers Co.
Robinson Clay Product Co.
Smith-Blair, Inc.
U. S. Pipe & Foundry Co.
R. D. Wood Co.

Pipe Jointing Materials (*see* Jointing Materials)

Pipe, Plastic
Amercoat Corp.
Evanite Plastic Co.

Pipe, Repairs
Centriline Corp.
Smith-Blair, Inc.

Pipe, Steel
American Pipe & Construction Co.
Armco Drainage & Metal Products, Inc.
Keasbey & Mattison Co.
A. O. Smith Corp.

Plastic Pipe Products
Amercoat Corp.
Evanite Plastic Co.
Keasbey & Mattison Co.

Publications
American City Magazine
Engineering News-Record
Liverpool University Press (England)
Public Works Magazine
Wastes Engineering Magazine
Water & Sewage Works

Pump Controls
Builders-Providence Div., B-I-F Industries
Burgess-Manning Co., Penn Instruments Div.
Chicago Pump Co.
Fischer & Porter Co.
Foxboro Co.
General Electric Co.
Minneapolis-Honeywell Regulator Co., Brown Instruments Div.
Rockwell Mfg. Co.
Smith & Loveless
Westinghouse Electric Corp.
Worthington Corp.
Zimmer & Francescon

dent, Georgia State Chamber of Commerce, Atlanta.

"Municipal Facilities for Industrial Development," by W. H. Weir, Director, Water Quality Service, Georgia Department of Public Health, Atlanta.

"Impact of Industrialization upon Municipal Financing," by B. M. Hall, Engineer, Wiedeman and Singleton, Atlanta.

"Waste Treatment Problems at the Atlanta Airport," by Fred A. Eidsness, Vice-President, Black and Associates, Gainesville, Fla.

"Waste Treatment Problems in Aluminum Fabrication," by Donald Luebke, Assistant Works Manager, American Art Metals, Atlanta.

"Effect of Metal Processing Wastes upon Sewage Treatment," by C. F. Griffin, Engineer, Lockheed Aircraft Corp., Marietta.

"A Review of the Fundamental Principles of the Trickling Filter," by R. S. Ingols, Professor, Applied Biology, Georgia Institute of Technology, Atlanta.

"A Report of Pilot Plant Studies With the Trickling Filter," by John Wiedeman, Engineer, Wiedeman and Singleton, Atlanta.

"Design and Operating Criteria of Plastic Film Filters," by D. H. Moeller, Field Development Engineer, Dow Chemical Co., Midland, Mich.

"Operating Experiences of Plastic Film Filters at the Rome Kraft Co., Rome, Ga.," by V. A. Minch, Sanitary Engineer, Mead Corp., Chillicothe, Ohio, and McDewain Sandlin, Chief Chemist, Rome Kraft Co., Rome.

Officers elected for 1961 are:

Chairman: Lewis Simonton, Griffin.
Vice-Chairman: McDewain Sandlin, Rome.
Secretary-Treasurer: Robert S. Ingols, Atlanta.

ROBERT S. INGOLS
Secretary-Treasurer

(*Continued on page 326a*)

ohmart

NUCLEAR SLUDGE DENSITY CONTROL *CUTS COSTS!*

One of eight Ohmart Sludge Density Gages at Pittsburgh's Allegheny Cty. Disposal Plant.

- Pump more solids—less liquid.
- Increase digester capacity and efficiency.
- Reduce heat and power costs.
- Handle less supernatant.

EXCLUSIVE OHMART ADVANTAGES:

Ohmart gages have a precision and repeatability of ± 2% of full scale range or better, with ranges as narrow as 0-10% solids available. Ohmart systems operate with high signal-to-noise ratio; are unique in their stability and simplicity. Low-drift circuit requires only 5-minute semi-monthly standardization check. Rugged gage construction withstands severe atmospheric and mechanical conditions. There are more Ohmart Nuclear Gages in operation in the waste disposal field than all others combined. **Look to Ohmart to yield high savings in your treatment plant. Performance to specification is guaranteed.** Write for Bulletin SD-2 for full details.

THE OHMART CORPORATION
2244 Bogen Street • Cincinnati 22, Ohio

ENGINEERING REPRESENTATIVES IN PRINCIPAL AREAS

Pumps, Airlift
Davco Corp.
Walker Process Equipment Inc.

Pumps, Chemical Feed
Proportioneers Div., B-I-F Industries

Pumps, Gas
Roots-Connersville Blower, Div. of Dresser Industries Inc.
Sutorbilt Corp.

Pumps, Grit
Nagle Pumps, Inc.

Pumps, Sewage
Alpha Ltd. (Switzerland)
American Well Works
Aurora Pump Div., The New York Air Brake Co.
Chicago Pump Co.
Davco Corp.
Eimco Corp.
Fairbanks, Morse & Co.
Gorman-Rupp Co.
Infilco Inc.
Marlow Pumps, Div. of Bell & Gossett Co.
Smith & Loveless
Sutorbilt Corp.
Wallace & Tiernan Inc.
Wemco Div., Western Machinery Co.
C. H. Wheeler Mfg. Co.
Worthington Corp.
Yeomans Brothers Co.
Zimmer & Francescon

Pumps, Sludge
Alpha Ltd. (Switzerland)
American Well Works
Aurora Pump Div., The New York Air Brake Co.
Ralph B. Carter Co.
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Fairbanks, Morse & Co.
Gorman-Rupp Co.
Hardinge Co., Inc.
Infilco Inc.
Komline-Sanderson Engr. Corp.
Marlow Pumps, Div. of Bell & Gossett Co.
Nagle Pumps, Inc.
Sutorbilt Corp.
Wallace & Tiernan Inc.
Wemco Div., Western Machinery Co.
Worthington Corp.
Yeomans Brothers Co.
Zimmer & Francescon

Pumps, Vacuum
Roots-Connersville Blower, Div. of Dresser Industries Inc.
Sutorbilt Corp.
C. H. Wheeler Mfg. Co.

Pumps, Water
American Well Works
Aurora Pump Div., The New York Air Brake Co.
Ralph B. Carter Co.
Chain Belt Co.
Chicago Pump Co.
Eimco Corp.
Fairbanks, Morse & Co.
Gorman-Rupp Co.
Marlow Pumps, Div. of Bell & Gossett Co.
Wallace & Tiernan Inc.
C. H. Wheeler Mfg. Co.
Worthington Corp.
Yeomans Brothers Co.
Zimmer & Francescon

Radiation Monitoring Equipment
Westinghouse Electric Corp.

Radios, Mobile
General Electric Co.

Recorders (*also see* Instruments, Recording, and Control)
Builders-Providence Div., B-I-F Industries
Burgess-Manning Co., Penn Instruments Div.
Fischer & Porter Co.
Fisher Scientific Co.
Foxboro Co.
General Electric Co.
Minneapolis-Honeywell Regulator Co., Brown Instruments Div.
Ohmart Corp.
Wallace & Tiernan Inc.

Refractory Building Materials
Carborundum Co.
Johns-Manville Sales Corp.
Robinson Clay Product Co.
Stebbins Engr. & Mfg. Co.

Safety Equipment
Vapor Recovery Systems Co.

Sampling Equipment
Chicago Pump Co.
Infilco Inc.
Lakeside Engineering Corp.

Sand, Gravel, and Stone
Graver Water Conditioning Co.

Screening Equipment
Alpha Ltd. (Switzerland)
American Well Works
Chain Belt Co.
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Infilco Inc.
Jeffrey Mfg. Co.
Link-Belt Co.
Walker Process Equipment Inc.
Zimmer & Francescon

Sedimentation Equipment (*also see* Clarifier Equipment)
Alpha Ltd. (Switzerland)
American Well Works
Ralph B. Carter Co.
Chain Belt Co.
Dorr-Oliver Inc.
Eimco Corp.
Graver Water Conditioning Co.
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Twenty-Year Index to *Sewage Works Journal*

Covers *Sewage Works Journal*, 1928-1948. Author, subject, and geographic. *144 pages. Buckram bound, $3.00. Order as Item Dex-20.*

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MISSOURI WATER POLLUTION CONTROL ASSOCIATION

The Annual Joint Meeting of the Missouri Water and Sewerage Conference, the Missouri Section of the American Water Works Association, and the Missouri Sewage and Industrial Wastes Association was held at the Hotel Governor, Jefferson City, Mo., Sept. 25–27, 1960.

It was at the business meeting of the sewage division on Sept. 26 that the membership voted to change the name to the Missouri Water Pollution Control Association.

Ray E. Lawrence, Federation Vice-President, was a speaker at both the business meeting and the joint session.

Among the outstanding papers presented were:

"Stream Survey, Shoal and Turkey Creeks, Cedar Creek Mine Wastes," by Joe Neel, USPHS, Kansas City, and Ed Lightfoot, Water Pollution Board, Jefferson City.

"Fayette Lagoon," by Joe Neel.

"Water and Sewage Facilities and the Highway Program," by Rex Whitton, Chief Engineer, Missouri State Highway Commission.

"Securing Surplus Property," by Cecil Jenkins, Director, State Agency Surplus Property.

"Industrial Waste Problems in Springfield," by Allen Mayfield, Sanitary Engineer, City of Springfield.

"Maintenance and Operation of Sewage Pumping Facilities," a panel discussion by representatives of: Smith & Loveless, Lenexa, Kans., Forslund Co., Kansas City, and Zimmer & Francescon, Moline, Ill.

"Sewer System Maintenance," by Porter Pryor, Sales Engineer, Delta Tool & Supply Co., Memphis, Tenn.

Officers elected for 1960–61 are:

Chairman: Werner F. Heidtke, St. Ann.

Vice-Chairman: Allen D. Mayfield, Springfield.
Secretary-Treasurer: Jack K. Smith, Jefferson City.
Director: William G. Riddle, Kansas City.

JACK K. SMITH
Secretary-Treasurer

NORTH DAKOTA WATER POLLUTION CONTROL ASSOCIATION

The newly-named North Dakota Water Pollution Control Association held its first Annual Meeting in conjunction with the 32nd Annual Convention of the North Dakota Water and Sewage Works Conference. This meeting was held Oct. 5–7, 1960, at the Grand Pacific Hotel, Bismarck, N. Dak. About 147 registered.

At the annual banquet, Glen J. Hopkins presented the Hatfield Award to Chester O. Sherva, Sewage Plant Operator, Fargo, for his outstanding works operation; and the Bedell Award to L. W. Veigel, Veigel and Bowlby Consulting Engineers, Dickinson, for his exceptional service to the North Dakota Association.

Among the papers of particular interest to those in the wastewater field were:

"Taste and Odor Control," by E. A. Sigworth, Industrial and Chemical Sales Division, West Virginia Pulp and Paper Co., Hillsdale, N. J.

A discussion of "Bismarck's City Municipal Facilities," with E. J. Booth, City Engineer, Bismarck, as chairman.

"Recent Developments in Municipal Facilities in South Dakota," by Charles E. Carl, State Sanitary Engineer, Pierre, S. Dak.

Report on Lagoon Symposium, by Jerome H. Svore, Regional Program

(*Continued on page 328a*)

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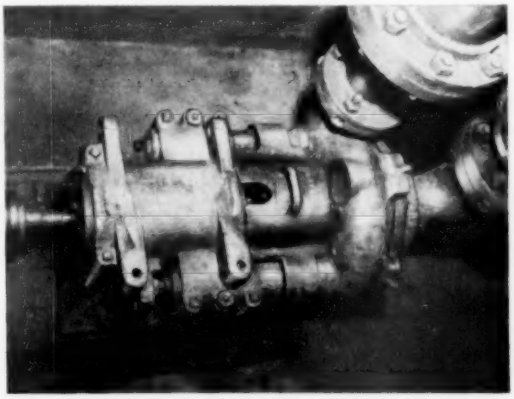

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Director, Water Supply and Pollution Control Activities, Public Health Service, Region VII, Dallas, Tex.

Municipal Sewage Systems and Treatment, with Oscar Bergman, Jr., Superintendent, Valley City Municipal Utilities, Valley City, as chairman.

At the business session the following officers were elected for 1960–61:

President: Richard Fuller, Southwest Fargo.
Vice-President: Glenn Berg, Minot.
Secretary-Treasurer: W. Van Heuvelen, Bismarck.

W. Van Heuvelen
Secretary-Treasurer

PACIFIC NORTHWEST POLLUTION CONTROL ASSOCIATION

The 27th Annual Meeting of the Pacific Northwest Pollution Control Association was held at the Marcus Whitman Hotel, Walla Walla, Oct. 20–22, 1960. Total registration was over 300 and was the largest meeting which the Association has ever had. About 250 attended the luncheon on the first day to hear Federation President Ray E. Lawrence talk on the changing responsibilities of the Federation and the factors which led up to the development of the Policy Statement.

At the well-attended banquet, Mr. Lawrence presented the Bedell Award to R. Trumbull Smith, Division Manager, Wallace and Tiernan, Seattle, Wash., and the Hatfield Award to James R. Burns, Superintendent of Sewage Treatment, Hillsboro, Ore.

Officers elected for 1960–61 are:

President: Raymond S. Fish, Medford, Ore.
Vice-President: C. S. Zickefoose, Walla Walla, Wash.
Director: R. Trumbull Smith, Seattle, Wash.

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Secretary-Treasurer: Gilbert H. Dunstan, Pullman, Wash.

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Secretary-Treasurer

ROCKY MOUNTAIN SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 24th Annual Meeting of the Rocky Mountain Sewage and Industrial Wastes Association, in conjunction with the Rocky Mountain Section of the AWWA, was held Oct. 24–26, 1960, at the Broadmoor Hotel, Colorado Springs, Colo. Approximately 185 registered; of these 65 were members of our Association. In addition, 74 ladies attended a program of their own, including a tour through the Air Force Academy and lunch at the Officers' Club.

Federation President Ray E. Lawrence, at the technical session on Monday, spoke on, "A Challenge to Our Industry." He also attended the business meeting which followed the luncheon, also on Monday.

Among the papers of particular interest to those in the wastewater field were:

"Coagulation and Ion Exchange in Radioactive Waste Treatment," by C. W. Christenson, U. S. Atomic Energy Commission, Los Alamos, N. Mex.

"Metropolitan Sewage Treatment Planning in Denver Area," by George Nez.

"Sewage Pumps," by John Bayless.

"Value of Plant Records," by John W. Hernandez, N. Mex. Department of Public Health, Santa Fe, N. Mex.

"Asbestos—Cement Pipe," by J. R. Cran.

"Recent Developments in Sludge Dewatering by Vacuum Filtration," by G. H. Teletzke, Director, Sanitary Engineering Research, Eimco Corporation, Palatine, Ill.

(*Continued on page 331a*)

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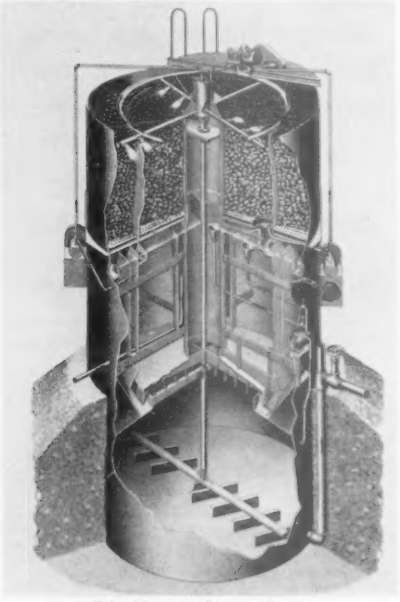
Personnel Wanted

Sewage plant superintendent—The Valley Community Services District is receiving applications for the position of sewage plant superintendent for a 2.5 mgd activated sludge treatment plant now being constructed. Position requires a man of 5 yrs recent experience in laboratory control and operation of activated sludge treatment plant, 2 yrs of which must be in a supervisory capacity. Those with a college degree in sanitary engineering or chemistry will be given preference. Superintendent will be responsible for all phases of plant operation. Salary—$8400 to $9600 depending on qualifications. Location is in rapidly growing portion of San Francisco Bay area. Position to be filled prior to Aug. 1, 1961. Send resumé to Valley Community Services District, Rt. 1, P. O. Box 556, Pleasanton, Calif., Att.: John H. Wright, General Manager.

Sanitary engineer with extensive experience in preliminary engineering and design of sanitary projects. Submit complete resumé of education, experience, and qualifications, together with salary requirements. Stanley Engineering Co., Hershey Bldg., Muscatine, Iowa.

tured in standard units ranging from $2 \times 2 \times 24$ ft high to $10 \times 10 \times 24$ ft high. The units and design data are discussed in a brochure of the Project Fabrication Corporation, 112–20 14th Ave., College Point 56, N. Y.

Package Plant—Bio-Pac is the name given to the fully automatic, factory-assembled, two-stage bio-filtration treatment unit recently introduced by the Link-Belt Co. Folder No. 2971 describing the unit is available at all district offices.



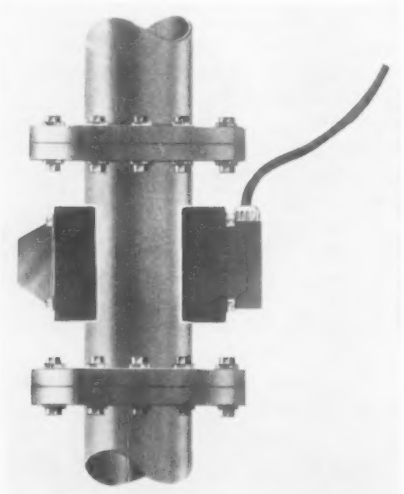
Bio-Pac package plant

Corrosion Resistant Pipe—A brochure from the "Nickel-Over-Steel" Division of M. C. Sheldon & Co., Inc., 350 Lexington Ave., New York, N. Y., describes how NIPHOS nickel-alloy-bonded steel pipe and tubing are being used to counter corrosion and iron contamination.

Cast Couplings—Permanent cast couplings for long life pipelines is the subject of a 12-page brochure, which describes and illustrates cast iron and asbestos-cement pipe couplings. Write to Smith-Blair, Inc., 535 Railroad Ave., South San Francisco, Calif.

Protective Coatings—Cold applications of bitumastic protective coatings are discussed in Bulletin T-97-61, available from Koppers, Inc., Tar Products Division, Pittsburgh 19, Pa.

Sludge Density Meter—Komline-Sanderson Engineering Corp., Peapack, N. J., is marketing a new sludge density meter called the Sludge Reader (see photograph). The instrument uses a low energy source of radiation to determine changes in solids concentration.



Titrimeters—Two new models of titrimeters have been announced by Fisher Scientific Co., 717 Forbes Ave., Pittsburgh 19, Pa. One is manual and the other automatic. The range of both models has been increased.

Pumps—Bulletin 553-2, "Motor-Driven Controlled Volume Pumps," featuring a selection data guide, materials selection charts, and capacity-pressure selection tables is offered by Milton Roy Co., 1300 E. Mermaid Lane, Philadelphia 18, Pa.

Chlorinator—A one-piece, compact, wall-mounted chlorinator is now available. Catalog Ref. No. 845.20-1, B-I-F Industries, 345 Harris Ave., Providence, R. I.

"Pipe Corrosion and Its Control," by Dana Kepner, Sales Engineer, Water Works, Sewerage and Power Equipment, Denver, Colo.

"The Role of the Consulting Engineer in the Industrial Wastes Field," by T. L. Moore, Gibbs and Hill, Inc., New York.

"Critical Loading of Oxidation Ponds," by Ronald T. McLaughlin, Division of Engineering, California Institute of Technology, Pasadena, Calif.

Officers for 1960–61 are:

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Vice-President: Verne E. Plath, Englewood, Colo.

Director: Anthony Rossi, Denver, Colo.

Secretary-Treasurer: John W. Hernandez, Santa Fe, N. Mex.

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ALASKA WATER MANAGEMENT ASSOCIATION

The newest member of the Federation, the Alaska Water Management Association, held its first meeting Jan. 14, 1961. The 13 persons in attendance were very enthusiastic about the new organization and its affiliation with the Federation.

The officers elected to serve for the year 1961 were:

President: LaMar Hubbs, Anchorage.

Vice-President (Northern Region): Harold Gillam, Fairbanks.

Vice-President (South-Central Region): Henry H. Staley, Anchorage.

Vice-President (Southeastern Region): Alfred Baker, Ketchikan.

Director: LaMar Hubbs.

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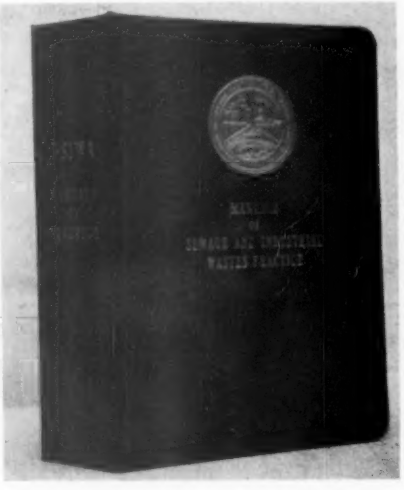

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The new binder for Federation Manuals of Practice may now be purchased from the Federation office at $2.00. The binder is of the multiple-wire type and has a capacity of two inches. The dark blue levant grain cover is handsomely impressed in gold-color with the Federation Seal on the front, and the title on the front and backbone of the binder. The binder will accommodate all manuals issued by the Federation and those planned for the future though the smaller page size of the joint manuals makes their inclusion inadvisable. These joint manuals will stand alone on a book shelf.

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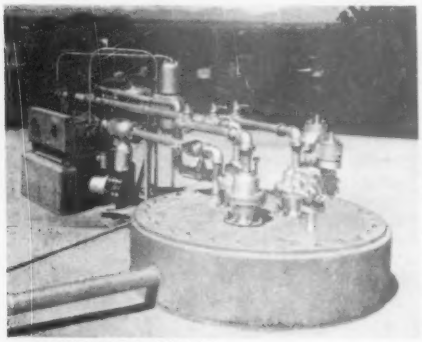

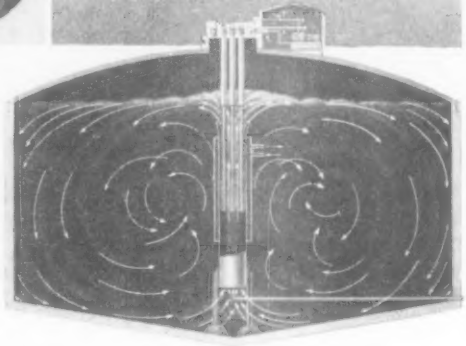

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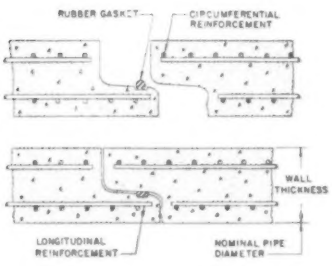

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W&T Compound-loop Control means true process control. Because it analyzes the end result and feeds back information which monitors your chlorinator, Compound-loop Control successfully achieves a closed-loop system. This means an operating range of greater than 100 to 1, plus round-the-clock supervision without extra labor.

And you can control free or total residual . . . use electric, pneumatic, or variable vacuum signals. W&T Compound-loop Control can be tailored to the physical layout of your system, your flow-metering equipment, your plant hydraulics. You build or convert to automation with maximum convenience, minimum expense.

For more information, write Dept. S-141.84

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